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ENERGY FROM THE WEST: A PROGRESS REPORT OF A TECHNOLOGY ASSESSMENT OF WESTERN ENERGY RESOURCE DEVELOPMENT

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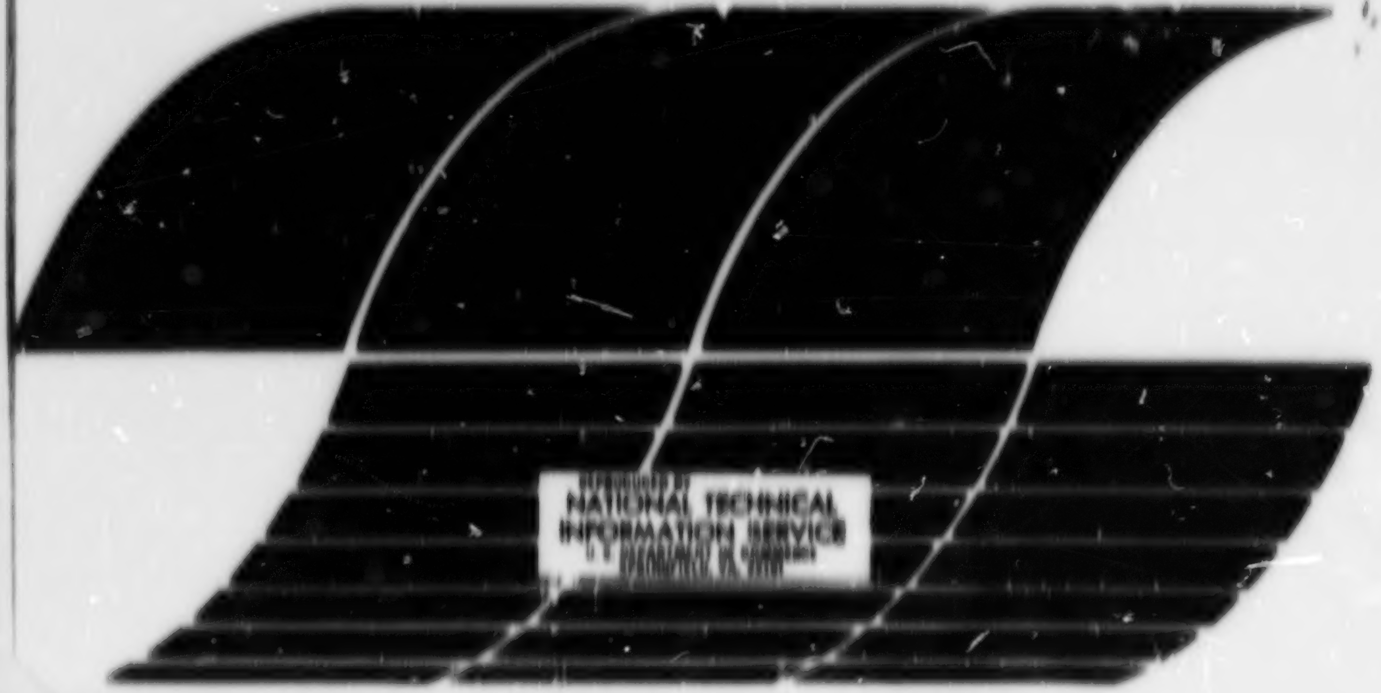

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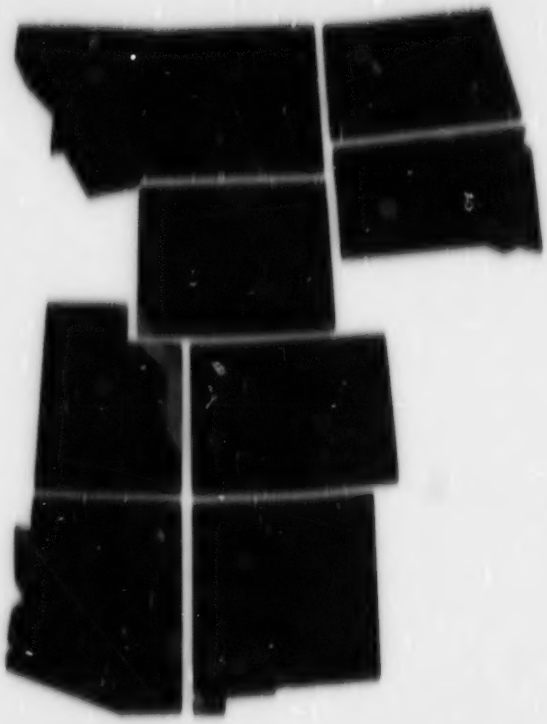

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FOREWORD

The production of electricity and fossil fuels inevitably creates adverse impacts on Man and his environment. The nature of these impacts must be thoroughly understood if balanced judgements concerning future energy development in the United States are to be made. The Office of Energy, Minerals and Industry (OEMI), in its role as coordinator of the Federal Energy/Environment Research and Development Program, is responsible for producing the information on health and ecological effects - and methods for mitigating the adverse effects - that is critical to developing the Nation's environmental and energy policy. OEMI's Integrated Assessment Program combines the results of research projects within the Energy/Environment Program with research on the socioeconomic and political/institutional aspects of energy development, and conducts policy - oriented studies to identify the tradeoffs among alternative energy technologies, development patterns, and impact mitigation measures.

The Integrated Assessment Program has utilized the methodology of Technology Assessment (TA) in fulfilling its mission. The Program is currently sponsoring a number of TA's which explore the impact of future energy development on both a nationwide and a regional scale. For instance, the Program is conducting national assessments of future development of the electric utility industry and of advanced coal technologies (such as fluidized bed combustion). Also, the Program is conducting assessments concerned with multiple-resource development in three "energy resource areas":

- Western coal states
- Lower Ohio River Basin
- Appalachia

This report describes the results of the first phase of the Western assessment. This phase assessed the impacts associated with three levels of energy development in the West. The concluding phase of the assessment will attempt to identify and evaluate ways of mitigating the adverse impacts and enhancing the benefits of future development.

The report is divided into an executive summary and four volumes:

I Summary Report
II Detailed Analyses and Supporting Materials
III Preliminary Policy Analysis
IV Appendices

Stephen J. Gage
Deputy Assistant Administrator
for Energy, Minerals, and Industry

PREFACE

This is a progress report of a "Technology Assessment of Western Energy Resource Development being conducted by an interdisciplinary research team from the Science and Public Policy Program (S&PP) of the University of Oklahoma and the Radian Corporation of Austin, Texas, for the Office of Energy, Minerals and Industry (OEMI), Office of Research and Development, Environmental Protection Agency (EPA) under contract No. 68-01-1916. This technology assessment (TA) is one of several being conducted under the Integrated Assessment Program established by OEMI in 1975. Recommended by an interagency task force, the purpose of the Program is to identify economically, environmentally, and socially acceptable energy development alternatives. The overall purposes of this particular TA are to identify and analyze a broad range of consequences of energy resource development in the western U.S. and to evaluate and compare alternative courses of action for enhancing desirable consequences and mitigating or eliminating undesirable ones.

The development of six energy resources (coal, geothermal, natural gas, oil, oil shale, and uranium)[1] in an eight-state area (Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming) is to be assessed. For this study, these states comprise the area referred to as either the "West" or "western U.S.". The time frame for the assessment is the period 1975 to 2000; however, selected impacts resulting from shutting down energy developments beyond 2000 are also analyzed.

The Project Director is Irvin L. (Jack) White, Assistant Director of S&PP and Professor of Political Science at the University of Oklahoma. Michael A. Chartock, Assistant Professor of Zoology and Research Fellow in S&PP, and R. Leon Leonard, Associate Professor of Aeronautical, Mechanical, and Nuclear Engineering and Research Fellow in S&PP, are Co-Directors of the S&PP portion of the research team. Team members from S&PP are: Steven C. Ballard, Visiting Assistant Professor of Political Science; Martha W. Gilliland, Systems Ecologist; Edward J. Malecki, Assistant Professor of Geography; Edward B. Rappaport, Visiting Assistant Professor of Economics; Rodney K. Freed, Graduate Research Assistant (Law); Timothy A. Hall, Graduate Research Assistant (Political Science), and Gary D. Miller, Graduate Research Assistant (Civil Engineering and Environmental

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[1] Geothermal resource development was not considered during the first year.

Science). Professors Ballard, Gilliland, Malecki, and Rappaport are also Research Fellows in S&PP. James L. Loud, a graduate student in Civil Engineering and Environmental Sciences, assisted with the air impact analyses.

F. Scott LaGrone, Vice-President and C. Patrick Bartosh, Program Manager, are the directors of the Radian part of the team. Team members at Radian are: Thomas W. Grimshaw, Staff Geologist; Joe D. Stuart, Manager, Atmospheric and Computer Sciences Division; David B. Cabe, Staff Meteorologist; B. Russ Eppright, Senior Engineer; David C. Grossman, Staff Meteorologist; Julia C. Lacy, Senior Biologist; Tommy D. Raye, Senior Chemical Engineer; and M. Lee Wilson, Senior Noise Control Engineer.

Several persons no longer with S&PP or Radian participated in the research upon which this report is based. Three are now in graduate school at other institutions: Cary N. Bloyd at Carnegie-Mellon University, Lori L. Sarbin at Ohio University, and Patrick Kangas at the University of Florida. Frank Calzonetti, a graduate student at the University of Oklahoma, is now working with another research group. Gerald M. Clancy, William D. Conine, and E. Douglas Sethness, Jr. have moved from Radian to other corporate positions, Clancy to become Vice-President of PROCON, Des Plaines, Illinois; Conine to become Environmentalist, Energy Minerals-U.S. & Canada, with Mobil Oil Corporation, Denver, Colorado; and Sethness to become Regional Manager of CDM Corporation, Austin, Texas.

This report is divided into three parts. Part I consists of five chapters that describe and summarize the results of the first year effort and briefly outline plans for the remainder of the project. In Part II, the results of the detailed site-specific and regional impact analyses are reported; and in Part III, the energy policy system is described and a more extended identification and definition of policy problems and issues is presented.

The scale and complexity of this TA have made it impossible to complete all of the component parts of a TA during the first year. The major effort has been focused on developing and testing an analytical framework, with special emphasis being placed on impact analyses. Consequently, this is not a report of a complete TA; it is a progress report on what has been accomplished during the first year of a multi-year study.

ABSTRACT

This is a progress report of a three year technology assessment of the development of six energy resources (coal, geothermal, natural gas, oil, oil shale, and uranium) in eight western states (Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming) during the period from the present to the year 2000. Volume I describes the purpose and conduct of the study, summarizes the results of the analyses conducted during the first year, and outlines plans for the remainder of the project. In Volume II, more detailed analytical results are presented. Six chapters report on the analysis of the likely impacts of deploying typical energy resource development technologies at sites representative of the kinds of conditions likely to be encountered in the eight-state study area. A seventh chapter focuses on the impacts likely to occur if western energy resources are developed at three different levels from the present to the year 2000. The two chapters in Volume III describe the political and institutional context of policymaking for western energy resource development and present a more detailed discussion of selected problems and issues. The Fourth Volume presents two appendices, on air quality modeling and energy transportation costs.

READER'S GUIDE

This report is divided into four volumes. In addition, an executive summary provides a brief description of the major research results of this western assessment.

Readers interested in a general description of the assessment results should read Volume I. Chapters I and II describe the context and methodological framework of the assessment. Chapter 3 provides a summary description of the impact analysis, e.g., water and air impacts, population changes, etc. Chapter 4 summarizes some policy implications of these results, although the assessment is still in the early stages of policy analysis at this time. Chapter 5 briefly describes what the reader can expect from the second phase of the project.

Readers interested in particular geographical areas might be interested in one or more of the six site-specific chapters (Chapters 6-11) of Volume II which describe in detail results pertaining to the following areas: Kaiparowits/Escalante, Utah; Navajo/Farmington, New Mexico; Rifle, Colorado; Gillette, Wyoming; Colstrip, Montana; and Beulah, North Dakota. Readers interested in site-specific air, water, socio-economic and ecological impacts will find these discussed in subsections 2, 3, 4, and 5, respectively, of each chapter in this volume. Chapter 12 in Volume II describes the results of the regional analyses. This chapter should be particularly valuable to readers interested in transportation, health, noise and aesthetic impacts, which are not discussed in the site-specific chapters, and subjects (such as water availability) which tend to be regional rather than site-specific in nature.

Volume III represents a first step in the identification, evaluation and comparison of alternative policies and implementation strategies. Chapter 13 presents a general overview of the energy policy system. Chapter 14 identifies and defines some of the principal problems and issues that public policymakers will probably be called on to resolve. The categories of problems and issues discussed are: water availability and quality, reclamation, air quality, growth management, housing, community facilities and services, and Indians.

Volume IV provides two technical appendices:

- a discussion of alternative approaches to modeling air quality in areas with complex terrain
- cost comparisons of unit trains, slurry pipelines and EHV transmission lines

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	alternating current
acre-ft/yr	acre feet per year
AEC	Atomic Energy Commission
AGA	American Gas Association
ACG	associations of government
API	American Petroleum Institute
AUM	animal unit month
BACT	best available control technology
bbl	barrel(s)
bbl/day	barrel(s) per day
bcf	billion cubic feet
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
Btu(e)	British thermal unit (electric)
Btu(th)	British thermal unit (thermal)
Btu	British thermal unit
CAA	Clean Air Act
CAP	Central Arizona Project
cfs	cubic feet per second
CO	carbon monoxide
COG	Council of Governments
dB	decibel
dBA	decibel(s) A-weighted
DC	direct current
DOI	Department of the Interior
EHV	extra-high voltage
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ERDS	energy resource development systems
ESP	electrostatic precipitator
FDA	Food and Drug Administration
FEA	Federal Energy Administration
FHA	Farm Home Administration
F.I.R.E.	Finance, Insurance, and Real Estate
FPC	Federal Power Commission
FWPCA	Federal Water Pollution Control Act
GACLA	Governors' Advisory Council on Local Affairs
gpd	gallons per day
gpm	gallons per minute
HC	hydrocarbons
HEW	Department of Health, Education, and Welfare
HMO	Health Maintenance Organization
HUD	Department of Housing and Urban Development

HVAC	high voltage alternating current
IUOE	International Union of Operating Engineers
kV	kilovolt(s)
lb/acre/yr	pounds per acre per year
LCRB	Lower Colorado River Basin
Ldn	day-night equivalent sound level
L.F.	load factor
MESA	Mining Enforcement and Safety Administration
mgd	million gallons per day
mg/l	milligrams per liter
mg/m^3	milligrams per cubic meter
MMcf	million cubic feet
MMcfd	million cubic feet per day
MMgpd	million gallons per day
MMmtpy	million metric tons per year
MMscfd	million standard cubic feet per day
MMtpy	million tons per year
MWe	megawatt-electric
NC	not calculated or not considered
NCA	National Coal Association
NEPA	National Environmental Policy Act
NERA	National Economic Research Associates
NIIP	Navajo Indian Irrigation Project
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NPC	National Petroleum Council
NRC	Nuclear Regulatory Commission
NSD	non-significant deterioration
NSPS	New Source Performance Standards
OCAW	Oil, Chemical and Atomic Workers International Union
OCS	outer continental shelf
OPEC	Organization of Petroleum Exporting Countries
ORV	off-road vehicle
pCi/g	picocuries per gram
pH	acidity/alkalinity
PNA	polynuclear aromatics
ppm	parts per million
PUD	planned unit development
Q	10^{15} British thermal units
Q	quad(s)
RD&D	research, development, and demonstration
REPO	Western Governors' Regional Energy Policy Office
RDS	Rural Development Service
SEAS	Strategic Environmental Assessment System
SIP	state implementation plan
SO_2	sulfur dioxide
S&PP	Science and Public Policy Program
SRI	Stanford Research Institute
SWIA	Southwest Wyoming Industrial Association
TA	technology assessment
tcf	trillion cubic feet

TDS	total dissolved solids
TOSCO	The Oil Shale Corporation
tpd	tons per day
tpy	tons per year
U.B.C.	Uniform Building Code
UCRB	Upper Colorado River Basin
ug/m^3	micrograms per cubic meter
UMRB	Upper Missouri River Basin
UMW	United Mine Workers
USGS	U.S. Geological Survey
ZDP	zero discharge of pollutants

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CONVERSION TABLE

LENGTH

1 foot = 3.048×10^{-1} meters

English to Metric

1 mile = 1.609 kilometers = 1609 meters
1 yard = .9144 meter = 91.44 centimeters

AREA

1 square foot = 9.29×10^{-2} square meters

English Equivalent

1 square mile = 640 acres

English to Metric

1 square mile = 2.590 square kilometers = 259.0 hectares = 2,590,000 square meters
1 acre = .004047 square kilometer = .4047 hectares = 4047 square meters

WEIGHT

English Equivalent

1 ounce (avoirdupois) = 437.5 grains (troy)

English to Metric

1 short ton (2,000 pounds) = .9072 metric tons = 907.2 kilograms
1 pound = .4536 kilogram
1 ounce = 28.349 grams

VALUES

1 watt = 3.4129 British thermal unit per hour = 1.433×10^{-2} kg-calories per minute
1 British thermal unit = 2.52×10^{2} calories
Centigrade degrees x 9/5 +32 = Fahrenheit degrees
1 erg = 9.480×10^{-11} British thermal unit
1 calorie = 3.968×10^{-3} British thermal unit
1 joule = 9.480×10^{-4} British thermal units
1 kilowatt = 5.692×10^{1} British thermal unit per minute
1 kWh = 3.413×10^{3} British thermal units

PRESSURE

English to Metric

1 pound per square inch (psi) = .0680 atmosphere = 703.1 kilograms per square meter

FLOW RATE

1 cubic foot per second = [illegible] per second
1 cubic foot per minute = 4.720×10^{-1} liters per second

English to Metric

1 cubic foot per second = 448.8 gallons per minute = 723.8 acre-feet per year = .02832 cubic meters per second
1,000,000 acre-feet per year = [illegible] cubic meters per second

VOLUME AND CAPACITY

1 barrel oil = 4.2×10^{1} gallons
1 million gallons per day = 1.54723 cubic feet per second
1 milligram per liter = 1 parts per million

English Equivalent

1 acre-foot = 43,560 cubic feet = 325,900 gallons
1 cubic yard = 202 gallons (liquid)
1 cubic foot = 7.481 gallons (liquid)

English to Metric

1 cubic yard = .7646 cubic meters = 764.6 liters
1 cubic foot = .02832 cubic meters = 28.32 liters

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PART I: SUMMARY REPORT

INTRODUCTION

Part I consists of five chapters. Chapter 1 sets the context of western energy resource development by identifying national energy goals, describing the role of western energy resources in the achievement of these goals, and enumerating the purposes and objectives of the 3-year study and this first-year report. Chapter 2 describes the conceptual framework being employed in the study and how it is being implemented by the Science and Public Policy Program-Radian interdisciplinary research team. The remaining three chapters summarize the results of the site-specific and regional impact analyses completed during the first year, briefly discuss some of the policy problems and issues that have arisen or are likely to arise, and outline plans for the remaining years of the study. Chapters 3 and 4 constitute a summary progress report of what the team has accomplished during the past year; they do not summarize the results of a complete technology assessment. More detailed impact analysis results are reported in Chapters 6-12, and a more extensive discussion of problems and issues is presented in Chapters 13 and 14. The plans for the remainder of the project are briefly outlined in Chapter 5 and will be elaborated in a separate work plan report.

CHAPTER 1

THE CONTEXT OF WESTERN ENERGY RESOURCE DEVELOPMENT

1.1 INTRODUCTION

Given its substantial and diverse energy resources, the western U.S. is a prime regional candidate for increasing domestic energy production. In fact, publicly announced coal development projects to be completed by 1985 would more than double the number of surface mines (46 to 97) and underground mines (44 to 91) in the eight-state area within which energy resource development is being assessed in this study.[1] These developments would increase coal production in the study area from 56.6 to 362.7 million tons per year.[2] During the same period, 60 new coal-fired electric power generating and 15 coal conversion facilities would be constructed.[3] Other proposed developments have been announced for oil shale and uranium, both of which exist in large quantities within the eight-state area.

In short, given a national energy policy of increasing domestic energy production and already announced plans, it appears that large-scale energy development within the western U.S. is an impending reality. The overall purpose of this study is to determine what the consequences of large-scale development are likely to be. This study is intended to contribute to a better understanding of the desirable and undesirable economic, environmental, institutional, social, and other consequences of large-scale energy development in the West. In particular, it is intended to inform policymakers concerning their policy options for either controlling or influencing the scale, rate, pattern, and timing of development. However, some of the factors that will help to determine what actually happens in western energy resource development are external to and in some cases beyond the control of policymakers in the region. In this chapter, several of these external factors are identified to set the context within which western energy resource development will take place. In a final section, the purposes and objectives of the study are then related to this context.

---

[1] The eight states are Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming. Data on existing mines are from U.S. Congress, House of Representatives Committee on Science and Technology, Subcommittee on Energy Research, Development and Demonstration. *Energy Facts II*, prepared by the Science Policy Research Division, Congressional Research Service, Library of Congress. Washington, D.C.: Government Printing Office, 1975. Data on planned development are from Corsentino, J.S., *Projects to Expand Fuel Sources in Western States*, Bureau of Mines Information Circular 8719. Washington, D.C.: Government Printing Office, 1976.

[2] *Ibid.*

[3] *Ibid.*

1.2 NATIONAL ENERGY GOALS

In his 1976 energy message, President Ford identified three major national energy policy goals: to reverse, in the near future, the U.S.'s increasing dependence on foreign oil; to achieve, by 1985, a national invulnerability to the disruptive potentials of oil embargoes; and to mobilize the nation's technology and resources to supply a significant share of the free world's energy needs after 1985.[1] These goals have been established in response to energy problems the U.S. has experienced during the past few years, and their overall objective is to lessen U.S. energy dependence on foreign sources.[2]

As the federal agencies charged with primary responsibility for developing energy policies for the U.S., the Energy Research and Development Administration (ERDA) and the Federal Energy Administration (FEA) have announced plans and programs designed to achieve the above goals.[3] In its 1976 *National Plan for Energy Research, Development and Demonstration*, ERDA calls for a broad-based strategy that includes both conservation and diversification of energy resource development. Several elements of this strategy call for developing energy resources in the western U.S. For example, a major short-term thrust of this program is to increase the direct use of coal; for the mid-term, high priority is assigned to obtaining liquid fuels from oil shale.[1] The plan also recognizes that these energy developments will result in "rapid development of extraction sites in the Northern Great Plains and Rocky Mountain Region...".[2]

---

[1] U.S., President. "1976 Energy Message." Cited in U.S., Energy Research and Development Administration. *A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future*, ERDA 76-1. Washington, D.C.: Government Printing Office, 1976, p. vii.

[2] U.S., President. "1975 State of the Union Message." Cited in U.S., Energy Research and Development Administration. *A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future*, ERDA 76-1. Washington, D.C.: Government Printing Office, 1975, p. vii.

[3] Other agencies with major energy responsibilities include the Department of the Interior and the Environmental Protection Agency.

FEA, in its 1976 *National Energy Outlook*, developed a comprehensive energy forecast and policy assessment. This forecast indicates that major increases in coal consumption are expected during the coming decade.[3] Thus, coal production in the West would increase sharply; for example, a 600-percent increase in Northern Great Plains coal production is anticipated by 1985.[4] This is almost 280 million tons more than the amount now being produced there. FEA's forecast also calls for the continued production of oil and natural gas in the West and for major increases in the production of other western energy resources (such as oil shale, uranium, and geothermal).[5]

1.3 WESTERN ENERGY RESOURCES

As stated earlier, the western U.S. contains a variety of energy resources, including coal, oil shale, uranium, oil, gas, and geothermal resources. The general distribution of these resources in the eight-state study area is shown in Figure 1-1. Coal is by far the most abundant energy resource in the eight-state area. As shown in Table 1-1, the area's 199 billion tons of demonstrated coal reserves represent a greater energy output potential than the other five study resources combined.

---

[1] U.S., Energy Research and Development Administration. *A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future*, 1976. Washington, D.C.: Government Printing Office, 1976.

[2] *Ibid.*, p. 53. The emphasis on developing western resources would be even greater if less of a contribution from nuclear power was anticipated.

[3] U.S., Federal Energy Administration. *1976 National Energy Outlook*. Washington, D.C.: Government Printing Office, 1976, p. 21.

[4] *Ibid.*, p. 32.

[5] *Ibid.*, pp. 61 and 133.

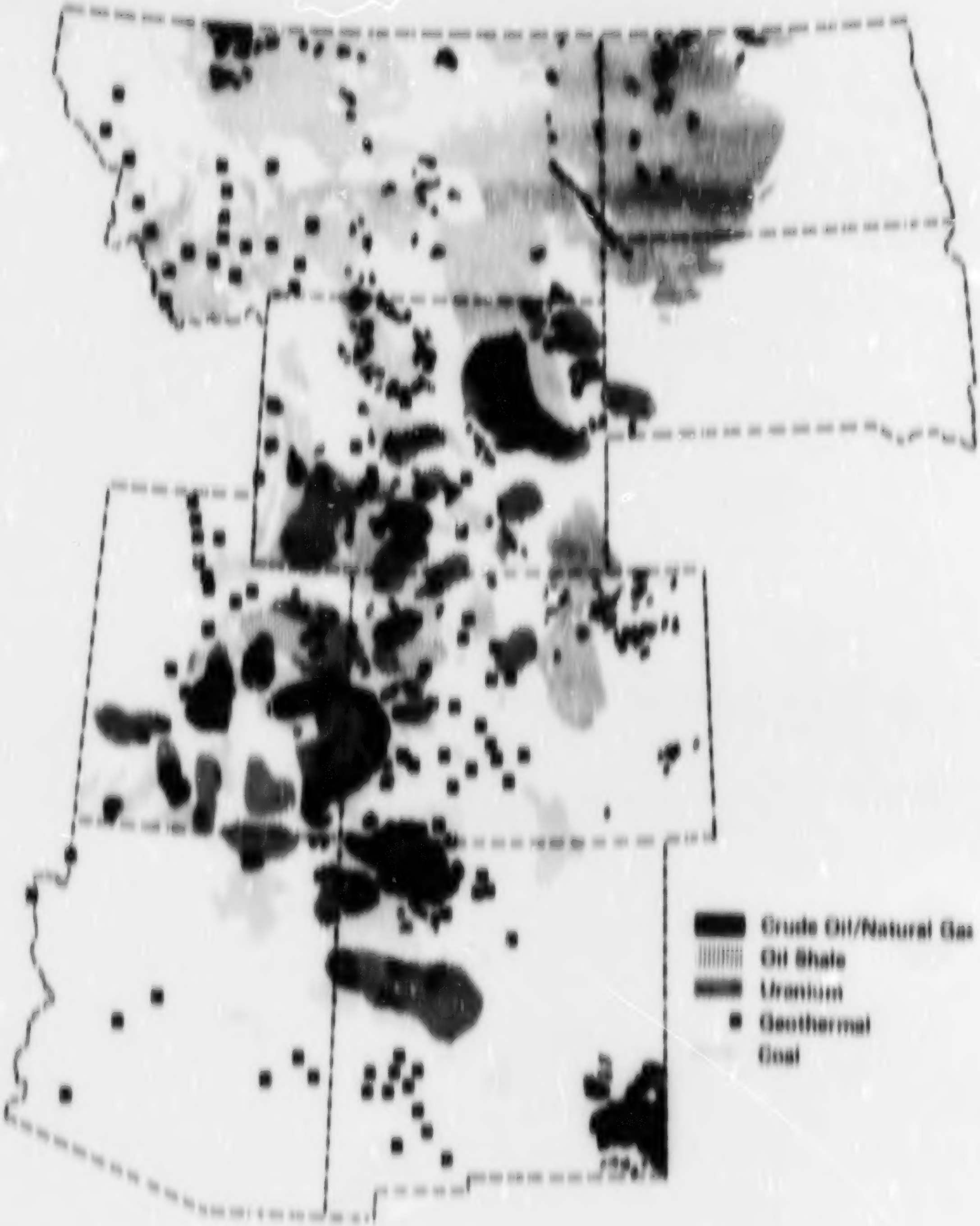

FIGURE 1-1: GENERAL DISTRIBUTION OF COAL, CRUDE OIL/NATURAL GAS, GEOTHERMAL, OIL SHALE, AND URANIUM RESOURCES IN EIGHT WESTERN STATES

TABLE 1-1: 1973 ANNUAL PRODUCTION AND PROVEN RESERVES OF SELECTED U.S. ENERGY RESOURCES IN EIGHT-STATE STUDY AREA

Resources	Annual Production[a]	Reserves[b]	
	1973 (10^{15} Btu's)	Reserves (10^{15} Btu's)	Percent of U.S. Total
Coal[c]	1.1	4,000	37
Oil[d]	2	14	7
Natural Gas[e]	1.9	22	8
Oil Shale[f]	0	2,340	100
Uranium[g]	5.5	170	90
Geothermal[c]	0	9	10

Btu's = British thermal unit(s)

[a] U.S., Congress, House of Representatives, Committee on Science and Technology, Subcommittee on Energy Research, Development, and Demonstration. Energy Facts, II, Committee Print. Washington, D.C.: Government Printing Office, 1975.

[b] Reserve figures for coal, oil, natural gas, oil shale, and uranium are from: House Subcommittee on Energy RD&D, Energy Facts, II. Figures for geothermal energy are from: White, D.F. and D.L. Williams, eds. Assessment of Geothermal Resources of the United States-1975, Geological Survey Circular 726. Washington, D.C.: Government Printing Office, 1975.

[c] Assumes an average of 10,000 Btu's/pound for western coal and 12,400 Btu's/pound for coal nationally.

[d] Assumes 5.6 million Btu's/barrel: 356 million barrel production and 2,527 million barrel reserves (42-gallon barrels).

[e] Assumes 1,031 Btu's/cubic foot for dry natural gas.

[f] University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975; and Radian Corporation. A Western Regional Energy Development Study, Final Report, 4 vols. Austin, Tex.: Radian Corporation, 1975.

[g] House Subcommittee on Energy RD&D. Energy Facts, II. Uranium production uses 1974 data.

Forty-eight percent of these coal lands are owned by the federal government, and substantial amounts are owned by Indian tribes.[1]

Coal production in the study area exceeded 70 million tons in 1973, more than 80 percent of which was surface-mined.[2] In addition to being low in sulfur content, many western coals occur in thick seams near the surface, which also enhances the attractiveness of these coals to developers. As a result, the number of surface coal mines in the West has increased during the past five years, while the number of underground mines has remained relatively unchanged.

Demonstrated oil shale reserves in the study area are estimated at 418 billion barrels (bbl).[3] As with coal, the federal government owns the major share of this resource.[4] However, unlike coal, no commerical oil shale production has yet taken place. In spite of the large quantity of oil shale resources, difficulties in planning, mining, and efficiently and economically converting the resource to a usable fuel have restrained development.[5]

Although highly dependent on ore quality and recoverability, estimates of uranium reserves in the study area range from 200 thousand to 300 thousand tons of yellowcake.[6] Large uncertanties surround the availability of uranium resources, most of which are located in northwestern New Mexico and in Wyoming. Subsurface mineral rights for about two-thirds of the lands thought to contain significant uranium resources are held by the federal government. In 1975, 11 thousand tons of yellowcake was produced in the area. This represented more than 90 percent of total U.S. production.

---

[1] U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Federal Coal Leasing Program, 2 vols. Washington, D.C.: Government Printing Office, 1974, p. 1-208.

[2] U.S., Federal Energy Administration. 1976 National Energy Outlook. Washington, D.C.: Government Printing Office, 1976, p. 172. Estimated total U.S. production was 639 million tons.

[3] University of Oklahoma, Science and Public Policy Program. Energy Alternatives: A Comparative Analysis. Washington, D.C.: Government Printing Office, 1975, pp. 2-7. This total represents only reserves of the highest quality category; this is virtually all of the nation's demonstrated oil shale reserves.

[4] Some ownership is in dispute and will probably have to be determined by the courts.

[5] S&PP, Energy Alternatives, Chapter 2. Oil shale has been developed in other countries.

[6] U.S., Energy Research and Development Administration. Statistical Data of the Uranium Industry, Jan. 1, 1975. Grand Junction, Colo.: Energy Research and Development Administration, 1975, p. 20.

Oil production from the West in 1973 was about 356 million bbl, a large percentage of the remaining proved western reserves of 2.5 billion bbl.[1] Gas production in the West was about 1.9 trillion cubic feet (tcf) in 1973 or almost 10 percent of the remaining reserves of 21 tcf. At current consumption rates, this quantity of gas would meet national needs for a single year.[2]

Although none of the Rocky Mountain and Great Plains states is using geothermal energy commercially, exploration and experimental development are taking place in several locations. Resources have not been accurately characterized, and estimates vary from as little as 1 thousand megawatts-electric (MWe)[3] of recoverable generating capacity to as high as 150 million MWe for the entire West.[4] Most estimates of known reserves range from 5 thousand to 6 thousand MWe of capacity,[5] and most of these resources are owned by the federal government.

1.4 SELECTED FACTORS AFFECTING LEVEL OF DEVELOPMENT

The actual pattern and development rates of the western energy resources described above will be contingent on a wide range of economic, social, and political factors such as energy demand, price, availability of development capital, availability of raw materials and skilled manpower, environmental policies and regulations, competing land uses, and attitudes toward development. Thus, although not the focus of this study, identification of some of these factors is important to understanding the context within which western energy development is and will continue to take place.

---

[1] "U.S. Reserves Fall Despite High Prices, More Drilling," Oil and Gas Journal, Vol. 74 (April 5, 1976), p. 82.

[2] Ibid., p. 83.

[3] A megawatt-electric is 1 million watts (1 thousand kilowatts) and is a standard measure of the amount of power, or electricity, that can be produced by a facility at any one time.

[4] Muffler, L.J.P., and D.E. White. Geothermal Energy Resources of the U.S., Geological Survey Circular 650. Washington, D.C.: Government Printing Office, 1972, p. 10; and Rex, Robert W., and David J. Howell. "Assessment of U.S. Geothermal Resources," pp. 59-68 in Kruger, Paul, and Carel Otte, eds. Geothermal Energy: Resources, Production, and Stimulation. Stanford, Calif.: Stanford University Press, 1973, p. 63.

[5] Geothermal depletion rates are not well understood. Some estimates assume a 50-year reserve or life.

Energy demand is affected by (among other things) price, availability, level of economic activity, and public perceptions. Demand projections indicate increases, although at lower growth rates than in the past.[1] However, the demand for electricity should continue to grow at a rate almost twice as fast as overall energy demand, and a gradual shift from the use of oil and gas to coal and nuclear materials for generating electricity is expected.[2]

The price of oil has largely been a product of the current seller's market in petroleum created by worldwide increases in oil consumption, decreasing production in consuming nations, and a greater ability of producing nations to act in concert. The Organization of Petroleum Exporting Countries (OPEC) has now gained control over the majority of oil producing operations and effectively determines the price of oil and, thereby, the price of many other energy resources.[3]

Recent oil price increases have made coal and uranium more economically attractive fuels and have stimulated interest in oil shale and geothermal resources, as well as in enhanced recovery of domestic oil. For example, the U.S. and several other countries have greatly increased their coal exports in recent years.[4] However, importing uranium for domestic use has been prohibited since the mid-1960's.[1] Although this policy has resulted in relatively high U.S. uranium prices, it has also provided stability for uranium mining operations in the Rocky Mountains and the Northern Great Plains.[2]

---

[1] The demand for energy has increased at a rate of about 7 percent per year over the past decade. During the past 2 years, however, U.S. energy demand has actually diminished, from 74 quadrillion British thermal units (Btu's) per year in 1973 to 71 quadrillion Btu's by the end of 1975. See U.S., Federal Energy Administration, "Overview," Monthly Energy Review (March 1976), p. 13.

[2] U.S., Federal Energy Administration. 1976 National Energy Outlook. Washington, D.C.: Government Printing Office, 1976, p. xxiv.

[3] The price of Organization of Petroleum Exporting Countries (OPEC) oil varied from $1.80 to $2.00 per barrel (bbl) between 1955 and 1970. In January 1972, the price was $2.18; in October 1973, it rose to $5.12. In January 1974, following the October embargo, OPEC oil was $11.65. In January 1976, the price was about $14.00 per bbl.

[4] In contrast to oil, trade in coal has been based on bilateral agreements between private purchasers and producers.

While high energy prices have stimulated new interest in western energy resources, there is no guarantee that prices will remain high. As noted, energy prices are being supported through the efforts of an international cartel, OPEC, and do not directly reflect production costs. Future decreases in price are quite possible, leading investors to be wary of investing in new projects (such as coal gasification), even though such projects might appear to be profitable at current prices. Risk factors such as these may significantly impede the availability of capital for certain kinds of western energy resource development.

The availability of raw materials, manpower, and equipment will also help to determine development schedules and production rates for western energy resource development. For example, many resource-rich sections of the study area have marginal water supplies. Thus, meeting the water needs of large-scale energy developments could result in inadequate water supplies for some users.

Large and/or rapid resource developments will be constrained by available skilled manpower pools. Also, foreseeable equipment problems range from the probable inadequacy of existing railroads to the questionable ability of industry to manufacture large numbers of specialized pieces of equipment (such as draglines and high-pressure vessels for gasification and liquefaction facilities) in a timely manner.

A wide range of environmental and social factors will also influence decisions to develop western U.S. energy resources. For example, environmental quality has been described as both a major reason for and a potential obstacle to development in the region. Low-sulfur western coal is an attractive substitute for more polluting fuels. Conversely, the "Big Sky" of the Northern Great Plains and the undisturbed vistas of the Rocky Mountains and canyonlands are widely recognized as national resources. In fact, there are current efforts in the Congress to produce federal legislation designed to maintain or improve the quality of such resources by, for example, establishing non-degradation standards for air.

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[1] Yager, Joseph A., and Eleanor B. Steinberg. *Energy and U.S. Foreign Policy*, a report to the Energy Policy Project of the Ford Foundation. Cambridge, Mass.: Ballinger, 1974, p. 21.

[2] *Ibid.*

Although only a few of these selected factors will substantially influence the development of western energy resource development, the above examples are sufficient to indicate that the energy developments assumed in this study may not take place. However, the sites and rates of the western U.S. energy resource developments that do occur will probably be largely determined by the range of factors, events, and policies either suggested in this chapter or analyzed in this study.

1.5 PURPOSE AND OBJECTIVES

As stated earlier, the overall purpose of this 3-year technology assessment (TA) are: to identify a broad range of the desirable and undesirable consequences likely to result from the development of western U.S. energy resources; and to identify, evaluate, and compare policies that will promote desirable consequences and eliminate or mitigate undesirable ones. During the first year, the research team's principal objective was to develop and begin implementation of an analytical framework for conducting a large-scale, complex TA. The analytical framework that has been developed is described briefly in Chapter 2 and detailed in the First Year Work Plan for a Technology Assessment of Western Energy Resource Development.[1] To date, the development and implementation of the framework has emphasized structuring the required impact analyses and reporting and integrating the results that these preliminary analyses have produced. While we believe that the research team has established the conceptual and analytical appropriateness of the framework, the impact analysis results reported in this progress report are incomplete and preliminary. Also, only the most tentative preliminary steps have been taken in the policy analyses. Our original expectations for what could be accomplished during the first year were higher, but the first-year accomplishments, as detailed in this report, have still been substantial.

As Chapter 2 and the first-year work plan indicate, producing a TA report that accomplishes the policy purposes of this study includes involving potential users of the final report in the research process. Further, if their participation is to be taken seriously, these potential users must see preliminary materials that are incomplete and unpolished. Thus, a draft of this report was widely circulated within the region and among federal agencies to solicit comments and suggestions. This final progress report incorporates changes responsive to the comments and suggestions produced by that solicitation.

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[1] White, Irvin L., et al. First Year Work Plan for a Technology Assessment of Western Energy Resource Development. Washington, D.C.: Environmental Protection Agency, 1976.

1.6 SCOPE

As the title indicates, the scope of the study is limited spatially to eight states in the western U.S.: Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming. This area is defined on the basis of the location of large quantities of the six energy resources on which the study is focused.

The time period covered by the study is 1975 to 2000.

1.7 OVERALL ASSUMPTIONS

The Science and Public Policy Program-Radian interdisciplinary research team incorporated a number of general assumptions into the research plan for this study. For example, the study assumes that the state of society will not change in any fundamental way during 1975-2000. The study also assumes that there will be no major war, extended economic depression, widespread mass social unrest, major restructuring of social and political structures and institutions, or drastic shifts in societal values.[1] Participation in energy policymaking is expected to continue to include a broad range of interests.

One of the most fundamental assumptions made by the research team is that policymakers must continue to deal with uncertainty in making policies for western U.S. energy resource development. While knowledge will increase, more data and information will be accumulated, and the consequence of development will be better understood, uncertainty will not be eliminated.

1.8 DATA SOURCES

Data used in this first-year study are drawn almost entirely from a variety of secondary sources such as environmental impact statements and reports prepared for government agencies. As noted in the objectives, data gaps and inadequacies are being identified. A separate report on data and research adequacy is being prepared.

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[1] These assumptions will be varied in the policy analyses to be performed during the next phase of the study.

CHAPTER 2

CONDUCT OF THE STUDY

2.1 INTRODUCTION

Technology assessment (TA) is the applied research tool used in this study to achieve the purposes and objectives stated in Chapter 1. As a research activity undertaken to inform policymakers, the development of TA has been motivated largely by the observation that the introduction, extension, and/or modification of a technology can produce a broad range of economic, environmental, social, institutional, and other consequences.[1] The fundamental purpose of a TA is to attempt to inform policymaking by:

1. Anticipating and systematically identifying, defining, and analyzing the range of consequences likely to result from the introduction, extension, and/or modification of a technology.
2. Identifying, evaluating, and comparing alternative policies for dealing with these consequences.
3. Identifying, evaluating, and comparing alternative strategies for implementing those policy options found to be feasible.[2]

Although both the term and research activity known as "technology assessment" have been in existence since the mid-1960's, neither an empirical theory nor a methodological orthodoxy has been developed.[1] The conceptual framework used by the interdisciplinary team conducting this study is a product of the applied policy research experiences of the University of Oklahoma's Science and Public Policy Program (S&PP) over the past six years. This framework and how it has been implemented by the S&PP-Radian research team during the first year of this study are briefly described in the following sections.

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[1] For a recent description of TA, see Arnstein, Sherry R. and Alexander N. Christakis, eds. *Perspectives on Technology Assessment*. Jerusalem, Israel: Science and Technology Publishers, 1975.

[2] Terms such as "feasibility" and "desirability" are defined on the basis of specified criteria at appropriate places in the substantive parts of this report.

2.2 CONCEPTUAL FRAMEWORK[2]

The general conceptual framework used in the TA is shown in Figure 2-1. Basically, the diagram shows that when a technology is deployed, impacts are produced by the interaction of the technology's inputs and outputs and the environmental conditions existing at the place of deployment.[3] Since some of these impacts may be perceived to be significant, public and/or private policymakers may select development policies designed to create or enhance desirable impacts and either eliminate or mitigate undesirable ones. In choosing from among the range of available policy alternatives, policymakers are limited by a variety of economic, legal, technological, social, institutional, and other constraints. These same constraints also limit the choice of a strategy for implementing the selected policy alternatives.

The variety of descriptive and analytical tasks implicit in this framework can be divided into three phases: Descriptive, Interactive, and Integrative. In the Descriptive Phase,

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[1] This lack of both a theory and methodology is discussed in Kash, Don E., and Irvin L. White. "Technology Assessment: Harnessing Genius." *Chemical and Engineering News*, Vol. 49 (November 29, 1971), pp. 36-41; and Arnstein, Sherry R., and Alexander N. Christakis, eds. *Perspectives on Technology Assessment*. Jerusalem, Israel: Science and Technology Publishers, 1975. For a review of methods and techniques applicable to technology assessment, see Coates, Joseph F. "Technology Assessment--A Tool Kit." *CHEMTECH* (June 1976), pp. 372-83.

[2] This conceptual framework is described in more detail in Chapter 2 of White, Irvin L., *et al.*, *First Year Work Plan of a Technology Assessment of Western Energy Resource Development*. Washington, D.C.: U.S., Environmental Protection Agency, 1976.

[3] Although perhaps not the most precisely correct term, impact is the term now used most often to denote effects. Dictionary definitions of the term do include the words striking and impingement, both of which produce effects. As used here, impact can refer to both an interaction and effects of interaction.

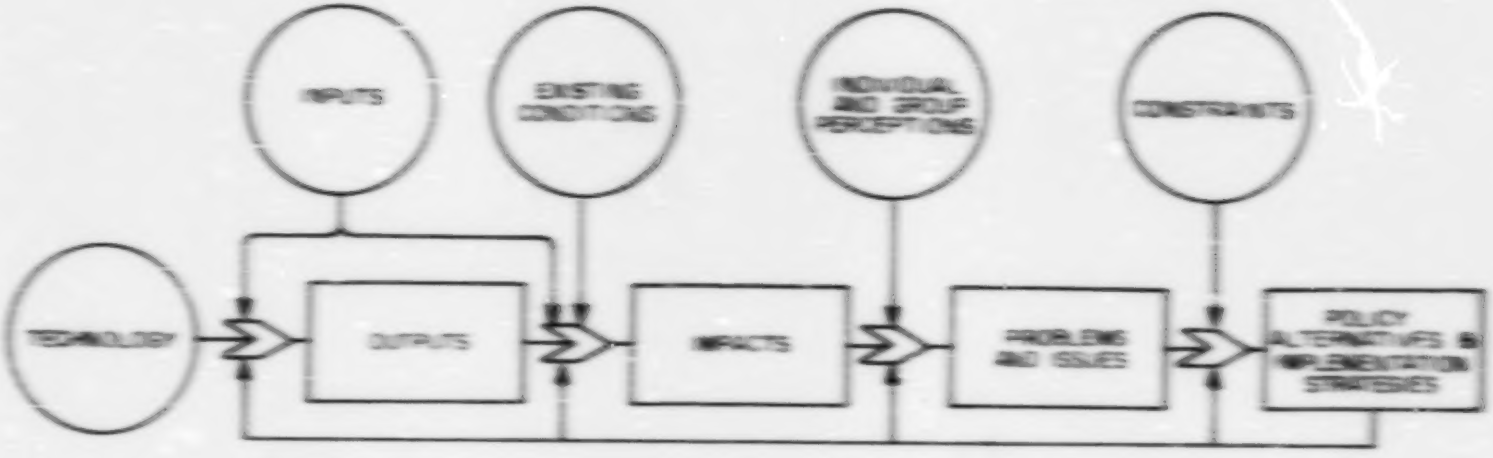
INPUTS
EXISTING CONDITIONS
INDIVIDUAL AND GROUP PERCEPTIONS
CONSTRAINTS
TECHNOLOGY
OUTPUTS
IMPACTS
PROBLEMS AND ISSUES
POLICY ALTERNATIVES & IMPLEMENTATION STRATEGIES

FIGURE 2-2: A CONCEPTUAL FRAMEWORK FOR ASSESSING PHYSICAL TECHNOLOGIES

technologies and existing conditions are delineated.[1] These descriptions include the identification of input requirements (such as water, capital, materials and equipment) and outputs and residuals (such as high-Btu gas, sulfur dioxide, and noise).[2] The descriptions of existing conditions include the laws and regulations that control the technology's deployment (such as land use and air and water quality laws and regulations) and climate, ecological system, and land-use patterns.

In the Interactive Phase, both the first and higher order impacts likely to result from the deployment of a particular technology under specified existing conditions are identified and analyzed. Given the lack of a standardized TA methodology, a variety of quantitative and qualitative methods are used to analyze and evaluate both standard category impacts (such as air and water quality) and synergistic impacts resulting from the interactions of other impacts. Finally, the significance of impacts is determined by applying criteria such as the magnitude of the impact, whether it is reversible, and how costs and benefits are distributed.[3]

In the Integrative Phase, problems, issues, and relevant policymaking systems are identified and defined. Although problems and issues will arise independently, impacts identified in the Interactive Phase will be a major source of problems and issues to which policymakers must respond. The analysis of problems and issues introduced from either or both sources includes identifying and evaluating alternative policies for responding to these problems and issues and developing alternative strategies for implementing alternative policies. In the Integrative Phase, both policy and implementation strategies are evaluated and compared on the basis of their costs and benefits.[1]

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[1] The term "existing conditions" refers to physical environmental conditions such as air dispersion potential and groundwater availability, ecological conditions such as plant and animal species, and social conditions such as social infrastructure and demography.

[2] Baseline data on technologies are presented in energy resource development systems (ERDS) which also include characterization of the resources and social controls (the laws and regulations that control the deployment of the technologies). The ERDS developed in this study will comprise part of the background and supporting materials to be made available. The existing conditions data required by the impact analyses are presented in Chapters 6 through 12.

[3] See Chapter 4 of White, Irvin L., *et al.* *First Year Work Plan for a Technology Assessment of Western Energy Resource Development*. Washington, D.C.: U.S., Environmental Protection Agency, 1976. The criteria for determining the significance of impacts are listed in Chapter 5 of the *First Year Work Plan*. The criteria actually used are specified when they are applied in Chapters 6 through 12 of this report.

2.3 INTERDISCIPLINARY TEAM APPROACH[2]

The conceptual framework briefly described above was implemented in this study by the S&PP-Radian research team. Since, as noted above, there is no generally approved TA theory or methodology, research team members were selected to provide the variety of disciplinary perspectives and the range of expertise in analytical methods and techniques needed to conduct the descriptive, interactive, and integrative tasks. Two kinds of research resources were needed: the in-depth, narrow expertise required to accomplish specific tasks, and a collegial capability to produce an integrated synthetic assessment product useful to policymakers. In short, while the TA could not be conducted without the research skills of narrowly trained specialists, no single research perspective or set of analytical tools could be allowed to dominate the study.

In July 1975, the research team began developing a detailed work plan for a preliminary TA which was expected to be completed within the first year of the project. In addition to providing greater insight into the structure and conduct of a study of this magnitude, two major benefits resulted from this planning effort. First, internal reviews of the work plan provided a means for determining whether the S&PP-Radian personnel could be molded into an effective interdisciplinary research team. Transforming a group of individuals into an interdisciplinary team always presents problems, but in this case accomplishing the transformation was especially challenging because members of the team were drawn from two very different kinds of organizations separated geographically by several hundred miles.

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[1] White, Irvin L., *et al*. *First Year Work Plan for a Technology Assessment of Western Energy Resource Development*. Washington, D.C.: U.S., Environmental Protection Agency, 1976. The various measures to be used in evaluating costs and benefits are also listed in Chapter 5 of the *First Year Work Plan*.

[2] For a more detailed discussion of the interdisciplinary team approach see: Kash, Don E., and Irvin L. White. "Technology Assessment: Harnessing Genius." *Chemical and Engineering News*, Vol. 49 (November 29, 1971), pp. 36-41; and White, Irvin L. "Interdisciplinarity," pp. 87-96 in Arnstein, Sherry R., and Alexander N. Christakis, eds. *Perspectives on Technology Assessment*. Jerusalem, Israel: Science and Technology Publishers, 1975.

The second benefit consists of extensive contacts that the research team established with persons and organizations in both the public and private sectors. These contacts were made to educate the team to inform and involve persons likely to be affected by western energy development and/or who might be potential users of the team's research reports. Most of the initial contacts were made in person. however, when the team's draft first-year work plan was prepared, approximately 500 copies were distributed throughout the region and among the energy and environmental agencies of the federal government. This distribution served at least two purposes: it informed interested individuals that the study was in progress, and it provided an opportunity for individuals and organizations to make comments and suggestions while the work plan was still in its formative stage.

The team structured its analyses by constructing seven scenarios. Six of these scenarios are site-specific, and the other covers the entire eight-state study area. These scenarios were constructed to provide for the analyses of a combination of existing conditions and technologies. The preliminary analytical results produced during the first year were then used to develop the generalizations about local, subregional, and regional impacts and critical technological and locational factors presented in Chapter 3. In subsequent years, these results will also be the starting point for policy analyses.

In preparing the first year work plan, the research team identified specific analytical tasks that had to be completed to achieve the TA's stated purpose and objectives. Within the overall structure provided by the conceptual framework, individual team members were assigned responsibilities for designing specific parts of the detailed work plan, and outside consultants were used to provide expertise lacking within the team itself. These work plan parts were then reviewed by the entire team, revised, and integrated into a preliminary draft.

This preliminary draft of the work plan was reviewed by consultants and the research team, then redrafted before being distributed to the individuals and organizations mentioned previously. On receipt of comments and suggestions generated by this distribution, another internal review was scheduled, and a critical review panel of key consultants was established. Thus, the final version of the first year work plan was the product of multiple internal reviews, consultant reviews, and the comments and suggestions received from approximately 100 respondents to the public and private sector distribution.

Shortly after the work plan was completed, an advisory committee was established. Members of this committee provide a link between the interdisciplinary research team and many of the key parties-at-interest likely to be affected by the development of western energy resources. At its first meeting, this committee reviewed the work plan, discussed a draft outline of this report, and made suggestions for changes and additions to the project during the second and third years. The committee also reviewed the draft first year progress report. This group will continue to act in an oversight advisory capacity throughout the study.[1]

Concurrent with the production of the work plan, the research team gathered data and drafted descriptions of the energy resource development systems[2] for the six energy resources included in the study. These describe the technologies deployed and existing conditions for each of the scenarios used to structure analyses during the first year. Data used in these descriptive tasks were taken almost exclusively from secondary sources. As with the work plan, individual team members were given specific assignments, and their work was subjected to an extensive critical review, primarily internally.

Together, the characterization of the technologies and existing conditions contained in these descriptions provided the information needed to determine impacts.[3] One or more team members were assigned primary responsibility for analyzing impacts in the categories of: air; water; social, economic, and political; ecological; health effects; noise; transportation; net energy; and aesthetics.[4]

Procedural and methodological details of the analyses conducted are provided in the impact analysis chapters in Part II, and a methodological appendix is included in this report. In general, analyses in each category began with the identification of initial changes likely to occur when the hypothesized energy developments take place. For example, the air impact analysis included determining changes in ambient concentrations of air pollutants; and the social, economic, and political impact analyses included determining gross population changes that should be expected. Identifying these initial changes also served as the beginning point for tracing the higher order impacts likely to occur (for example, secondary air quality and social infrastructure impacts).

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[1] However, the advisory committee is not responsible for nor do its members necessarily endorse or agree with the content of the work plan or this report.

[2] Draft versions of six energy resource development systems (ERDS) are now being circulated separately for review. These ERDS include a description of the resource base, the technologies used to develop the resources, the inputs and outputs (including both products and residuals) for each technology, and the laws and regulations that apply to the deployment and operation of each technology.

[3] This should not be interpreted to mean that all information and data requirements have been adequately met. The team collected the best available information and data for use in the impact analyses conducted during the first year. A separate report is being prepared on data availability and adequacy and research needs.

[4] Impacts were analyzed at four levels: local, subregional, regional, and national. However, not all impacts were analyzed at all four levels. See the Introduction to Part II and Chapters 6 through 12.

In many instances, an impact in one category will produce an impact in another. For example, increased concentrations of an air pollutant may produce a health effect. Consequently, information on these kinds of impacts was exchanged among team members as impacts were determined within each category. However, the planned systematic tracing of impacts within and among categories is incomplete at present.

The results of the analyses conducted by individual team members were also reviewed using the internal team critiquing process described above. This review mechanism is intended to provide a check on the adequacy of the analyses, to insure the transfer of impact information among team members, and to insure that synergistic impacts are not overlooked.

As shown in Part II, these separate impact analyses were brought together in an overall analysis of each of the seven scenarios. In turn, these seven summaries provided a basis for the tentative generalizations concerning the technological and existing conditions relationships that are formulated in Chapter 3. Had there been time, these impact summaries and generalizations would have been the beginning point for policy analyses. Since these research results were not available, the policy analyses are just getting underway at this time. Consequently, Chapters 4, 13, and 14 are limited to a preliminary description of the social and institutional context for western energy resource development and the identification and preliminary definition of a few selected problem and issue categories. In no sense are these chapters a report of policy analyses that have been completed. The preliminary identifications and definitions are included to indicate where the team stands in acquiring background knowledge on the particular problems and issues and to elicit suggestions and comments from reviewers. As described in Chapters 4 and 5, now that the initial compilation of the results of impact analyses is available, the major emphasis of the project will be shifted to policy analyses.

2.4 SUMMARY

The "Technology Assessment of the Western Energy Resource Development" being conducted by the S&PP-Radian research team is a multi-year effort; this report describes the progress the team has made during the first year. A major effort has been to develop and implement a conceptual framework based on the observation that the interaction of development technologies with the conditions existing at their deployment locales will produce impacts, some of which will require advance planning and the establishment of guidelines by public and/or private policymakers.

In implementing the conceptual framework, the team defined the descriptive, interactive, and integrative tasks implicit in it and structured the study by constructing seven energy resource development scenarios specifying combinations of technologies and existing conditions. On the basis of the analyses of the seven scenarios, the team was able to formulate a few preliminary generalizations about what impacts will occur and to begin to consider what can be done to deal with them.

Given the scale and complexity of this TA, it has not been possible to complete even a preliminary TA during the first year. This progress report reflects the emphasis that has been devoted to impact analyses. Although these analyses must be extended and refined, the first-year effort provides a basis for shifting our emphasis from descriptive and interactive to integrative tasks, and from impact analyses to policy analyses during the remaining years of the study.

CHAPTER 3

THE IMPACTS OF WESTERN ENERGY RESOURCE DEVELOPMENT: SUMMARY AND CONCLUSIONS

3.1 INTRODUCTION

This study is to assess the development of coal, geothermal, natural gas, oil, oil shale, and uranium resources in eight states. Development alternatives for all these resources, except geothermal, have been considered during the first year, although coal resource development has been emphasized. As shown in Figure 3-1, coal development alternatives include surface and underground mining, on-site electrical power generation, gasification, liquefaction, and the export of raw coal by unit train and slurry pipeline. Electricity will be transported by extra-high voltage transmission lines, and gases and liquids by pipelines.[1]

Underground mining, surface retorting, and transport by pipeline make up the oil shale resource development alternative considered during the first year. Oil and natural gas development is limited to conventional drilling and transportation by pipeline. Uranium development is limited to surface mining, milling, and rail transportation.

As described in Chapter 2, the organizing concept used to structure the impact analyses is based on the observation that impacts occur when a technology interacts with the conditions that exist at the location where the technology is deployed.

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[1] Development alternatives are described in more detail in the Introduction to Part II and in Chapters 6-12. Detailed descriptions of the technological alternatives for developing each of the six resources are presented in energy resource development systems prepared as background and supporting materials for the impact and policy analyses. These descriptions provide baseline data on the technologies (demands, products, and residuals), characterize the resources, and describe the principal laws and regulations that apply to the deployment and operation of the technologies. See White, Irvin L., et al. Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

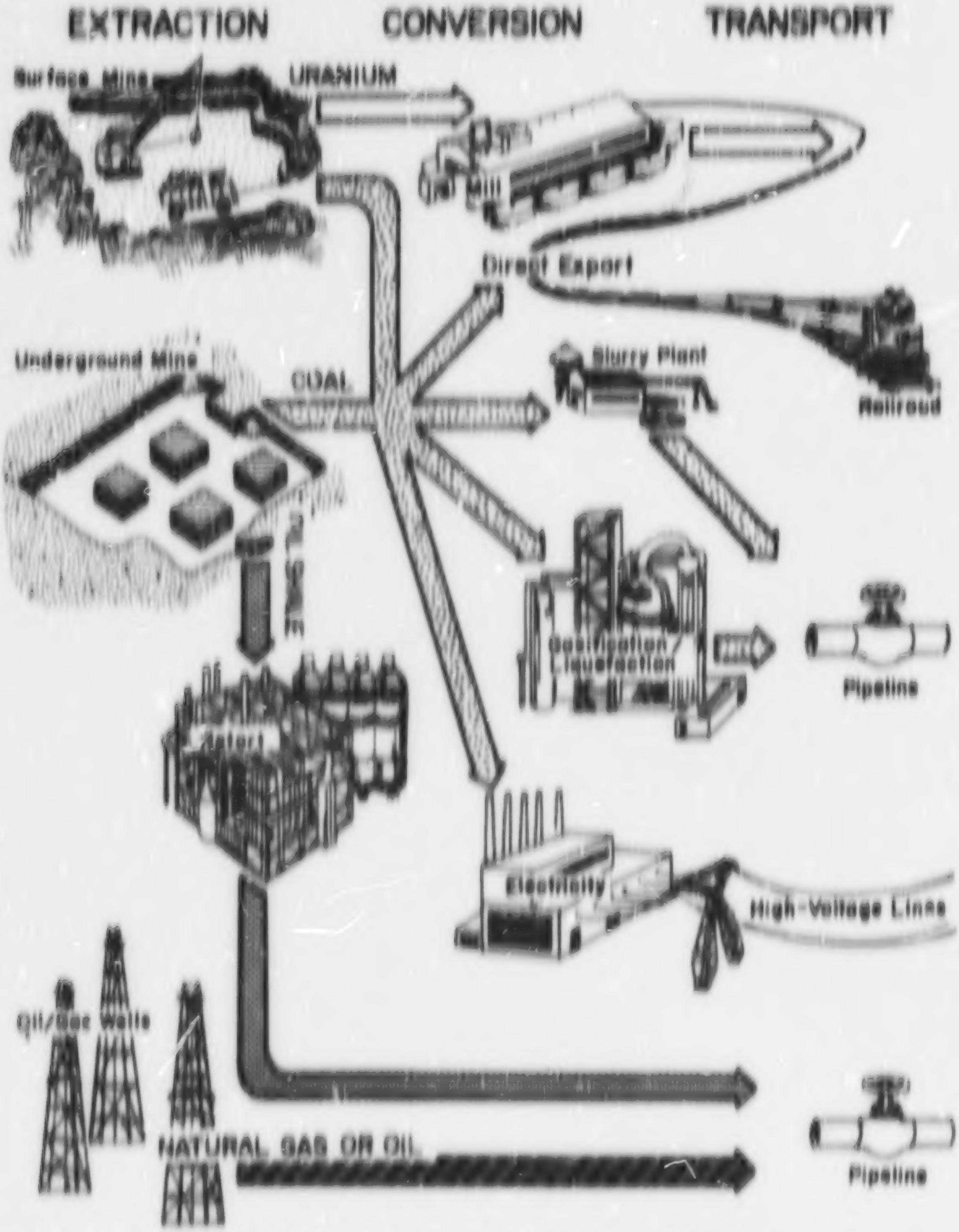

FIGURE 3-1: ENERGY RESOURCE DEVELOPMENT

What these impacts are depends on: the demands the technology creates and the products and residuals it produces;[1] the physical and social environmental conditions that exist at the site (such as present population, lifestyle, topography, and climate); and the scale, rate, pattern, and timing of the development.

Seven energy resource development scenarios were used to organize various combinations of the development alternatives shown in Figure 3-1 and to structure the impact analyses conducted during the first year. Six of these scenarios call for the deployment of typical energy development technologies at representative sites in the eight-state study area. The seventh scenario calls for three levels of energy development within the eight-state area from the present to the year 2000.

Table 3-1 identifies the six sites selected, lists hypothetical energy developments at each, and indicates when each development is to begin and facilities are to be operational. As Table 3-1 indicates, several process mixes, development schedules, and scales of development have been included in the scenarios. The table reflects the emphasis given to coal during the first year of the project. The development hypothesized at each site is *not* intended to correspond to the plans that individual energy companies have announced. The number and mix of technologies was chosen to provide for the analysis of a variety of technology and location combinations.

Table 3-2 indicates the total quantities of energy required from the Western U.S. at three national levels of energy consumption in 1980, 1990, and 2000. This table also shows the role of each of the six resources in producing these total quantities.[2] To complete the picture of the regional development

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[1] Outputs include both products and residuals. Products are what the technology is intended to produce, such as syncrude and shale oil. Residuals are by-products, such as sulfur dioxide and particulates.

[2] The three levels of development, or cases, were established using the Stanford Research Institute's (SRI) interfuel competition model. The model and the three cases are described in Chapter 12 and in more detail in SRI Decision Analysis Group, Cazalet, Edward, *et al. A Western Regional Energy Development Study: Economics*, Final Report, 2 Vols. Menlo Park, Calif.: Stanford Research Institute, 1976. The three levels now appear to be too high and the resource mix called for inappropriate. Both the levels and mix will be modified for the remainder of the project. These modifications will be described in White, Irvin L., *et al. Work Plan for Completing a Technology Assessment of Western Energy Resource Development*. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

TABLE 3-1: SITE-SPECIFIC ENERGY DEVELOPMENTS[a]

Site	Hypothetical Energy Development	Start-Date	On-Line
Kaiparowits/ Escalante	Coal-Deep Mine-Electrical Generation-Transmission (3,000 Mwe)	1976	1985
	Coal-Deep Mine-Electrical Generation-Transmission (3,000 Mwe)	1979	1987
Navajo/ Farmington	Coal-Surface Mine-Electrical Generation-Transmission (3,000 Mwe)	1982	1985
	Coal-Surface Mine-Lurgi High-Btu Gasification-Pipeline (250 MMcfd)	1977	1980
	Coal-Surface Mine-Synthane High-Btu Gasification-Pipeline (250 MMcfd)	1987	1990
	Coal-Surface Mined Synthoil Liquefaction-Pipeline (100,000 bbl/day)	1997	2000
Rifle	Oil Shale-Deep Mine-TOSCO II-Upgrade-Pipeline (50,000 bbl/day)	1982	1985
	Oil Shale-Deep Mine-TOSCO II-Upgrade-Pipeline (100,000 bbl/day)	1987	1990
	Coal-Deep Mine-Electrical Generation-Transmission (1,000 Mwe)	1977	1980
	Oil-Wells-Pipeline (400 wells, 50,000 bbl/day)	1982	1985
Gillette	Coal-Surface Mine-Rail Transport (25 MMtpy)	1977	1980
	Coal-Surface Mine-Slurry Pipeline (25 MMtpy)	1982	1985
	Coal-Surface Mine-Electrical Generation-Transmission (3,000 Mwe)	1977	1985
	Coal-Surface Mine-Lurgi High-Btu Gasification-Pipeline (250 MMcfd)	1982	1985
	Coal-Surface Mine-Synthane High-Btu Gasification-Pipeline (250 MMcfd)	1992	1995

TABLE 3-1: (Continued)

Site	Hypothetical Energy Development[a]	Start-Date	On-Line
Gillette	Coal-Surface Mine-Synthoil Liquefaction-Pipeline (100,000 bbl/day)	1997	2000
	Gas-Oil Wells-Beneficiation-Pipeline (250 MMcfd)	1976	1979
	Uranium-Surface Mine-Milling-Rail (1,000 metric tons yellowcake per year)	1982	1985
Colstrip	Coal-Surface Mine-Electrical Generation-Transmission (3,000 MWe)	1977	1985
	Coal-Surface Mine-Lurgi High-Btu Gasification-Pipeline (250 MMcfd)	1987	1990
	Coal-Surface Mine-Synthane High-Btu Gasification-Pipeline (250 MMcfd)	1992	1995
	Coal-Surface Mine-Synthoil Liquefaction-Pipeline (100,000 bbl/day)	1997	2000
Beulah	Coal (Lignite)-Surface Mine-Electrical Generation-Transmission (3,000 MWe)	1977	1980
	Coal (Lignite)-Surface Mine-Lurgi High-Btu Gasification-Pipeline (250 MMcfd)	1979	1982
	Coal (Lignite)-Surface Mine-Lurgi High-Btu Gasification-Pipeline (250 MMcfd)	1974	1987
	Coal (Lignite)-Surface Mine-Synthane High-Btu Gasification-Pipeline (250 MMcfd)	1992	1995
	Coal (Lignite)-Surface Mine-Synthane High-Btu Gasification-Pipeline (250 MMcfd)	1997	2000

bbl/day = barrels per day
MMcfd = million cubic feet per day
MMtpy = million tons per year
MWe = megawatts-electric

[a] See Chapter 1, White, Irvin L., *et al.* First Year Work Plan for a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, 1976. As explained in Chapter 1, these hypothetical developments are not intended to be identical with announced plans for these same sites.

TABLE 3-2: REGIONAL ENERGY DEVELOPMENTS

Resources and Levels of Development[a]	Total U.S. Production (Q's)			Projected Production in the Eight-State Study Area					
				1980		1990		2000	
	1980	1990	2000	Q's	Percent U.S. Total	Q's	Percent U.S. Total	Q's	Percent U.S. Total
Coal									
Nominal	15.22	25.12	50.46	5.03	33.3	12.61	50.2	29.89	58.7
Low Demand	13.36	20.24	38.65	4.28	32.0	9.80	48.4	22.11	57.2
Low Nuclear Availability	17.72	35.43	71.01	6.19	34.9	17.50	49.4	39.48	55.6
Oil Shale									
Nominal	.012	.92	8.07	.012	100.0	.92	100.0	8.07	100.0
Low Demand	.003	.86	6.68	.003	100.0	.86	100.0	6.68	100.0
Low Nuclear Availability	.003	.84	7.86	.003	100.0	.84	100.0	7.88	100.0
Uranium Fuel									
Nominal	5.34	13.90	26.10	4.77	89.3	12.64	91.1	23.75	91.0
Low Demand	4.55	10.42	18.80	4.11	91.0	9.46	91.0	17.11	91.0
Low Nuclear Availability	1.48	.78	.34	1.35	91.2	.71	91.0	.31	91.2
Gas (Methane)									
Nominal	23.73	26.02	18.34	1.97	8.3	2.08	8.0	1.06	5.8
Low Demand	23.12	24.61	17.69	1.99	8.6	1.89	7.7	1.19	6.7
Low Nuclear Availability	24.30	26.55	18.79	1.97	8.1	2.10	7.9	1.09	5.8
Domestic Crude Oil									
Nominal	21.10	25.96	22.79	1.69	8.0	1.32	5.1	1.03	4.5
Low Demand	21.16	25.37	20.62	1.74	8.2	1.34	5.3	.92	4.5
Low Nuclear Availability	21.02	26.02	23.36	1.66	7.9	1.30	5.0	1.03	4.4
Total Q's									
Nominal	65.39	91.02	126.29	13.46		28.57		63.86	
Low Demand	62.33	81.48	104.44	12.36		23.35		47.98	
Low Nuclear Availability	64.52	88.67	120.37	11.16		21.45		48.78	

Q = 10^{15} British thermal units. One Q ≈ 170 million barrels of oil, ~40 million tons of western coal, or one trillion cubic feet of natural gas.

[a] See Chapter 11 for a description of the three levels of development.

being assessed, Table 3-3 identifies the number and kinds of facilities that would be required for each resource.

Together, these seven scenarios provide an organizing analytical structure for estimating impacts likely to occur when typical energy development technologies are deployed under representative existing conditions. Results of the six site-specific impact analyses are reported in Chapters 6-11. These results are the basis for the conclusions concerning local impacts and generalizations about technologies and existing conditions included in this chapter. Likewise, the levels of development, facilities, and time frame outlined in Tables 3-2 and 3-3 provide the structure for the analysis of regional impacts described in Chapter 12; the results of those analyses are the basis for the summary discussion of regional impacts and the factors which cause them.

At this stage in the study, the research team's impact analyses are incomplete. For example, within the time constraints of the first year, it has not been possible to give sufficient attention to technological alternatives (such as other environmental controls), systematically tracing impacts, the introduction of impacts from one impact analysis category into another, possible synergistic effects, and sensitivity and parametric analyses. Consequently, the results reported in Chapters 6-12 and summarized in this chapter are tentative and preliminary. The first-year effort has emphasized developing and testing an analytical structure capable, over the duration of the study, of providing results on which to base well-informed, meaningful policy analyses. In implementing this analytical framework, a few apparently new findings have emerged and much "common knowledge" about the impacts of energy development has been confirmed.

This chapter summarizes what the Science and Public Policy-Radian research team has learned to date about impacts and draws some tentative conclusions about the technological and locational interactions. Specifically, the goal is to identify those technological and locational factors that produce significant impacts.[1] These conclusions are discussed in seven

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[1] The criteria used to determine the significance of an impact are: magnitude; rate; reversibility; distribution; standards; uniqueness; uncertainty; social and political values; and national goals. See Chapter 5 of White, Irvin L., et al. First Year Work Plan for a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, 1976.

TABLE 3-3: REQUIRED REGIONAL FACILITIES

Facility	Facility Size	Number of Facilities Required[a]								
		Nominal			Low Demand			Low Nuclear Availability		
		1980	1990	2000	1980	1990	2000	1980	1990	2000
Coal Mines[b]	5 MMtpy	60	149	351	51	116	260	73	207	486
Gasification	250 MMscfd	0	3	47	0	2	25	0	0	42
Liquefaction	100,000 bbl/day	0	0	1.5	0	0	1	0	0	1
Electric Power Generation	1,200 MWe	6	18	23	6	13	17	9	26	48
Oil Shale	100,000 bbl/day	0	3	42	0	5	35	0	4	42
Uranium Fuel	1,000 tpy of yellowcake	16	42	79	14	32	57	5	2	1
Gas (Methane)	250 MMscfd	22	23	22	22	21	13	22	23	22
Domestic Crude Oil	100,000 bbl/day	8	6	5	8	6	4.5	8	6	5

bbl = barrels

MMscfd = million standard cubic feet per day

MMtpy = million tons per year

MWe = megawatts-electric

tpy = tons per year

[a] Total number required in the given year.

[b] This includes the mines for export, gasification, liquefaction, and electric power generation.

categories: air, water; social, economic, and political; ecological; health effects; transportation; and aesthetics and noise. Impacts within each category are identified as being primarily a consequence of the technology, conditions existing at the deployment location, and the interaction of technological and locational factors.

3.2 AIR QUALITY[1]

HIGHLIGHTS

- **CRITICAL FACTORS**
  - *Two technological factors can significantly affect air quality impacts: emissions quantities and labor intensiveness.*
  - *Three locational factors can also significantly affect these impacts: coal characteristics, dispersion potential, and topography.*
- **EMISSIONS**
  - *More SO_2, particulates, NO_x, and CO are emitted by electric power plants than by any other conversion technology.*
  - *Less of these four criteria pollutants are emitted by gasification facilities than by any other conversion technology.*
- **AMBIENT AIR STANDARDS**
  - *Peak ground-level concentrations of particulates, NO_x, and hydrocarbons produced by energy related urban development are usually higher than those produced by the energy facilities themselves.*

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[1] The conversion technologies considered are coal-fired electric power plants (with 80-percent removal of sulfur dioxide and 99-percent removal of particulates), Lurgi and Synthane gasification, Synthoil liquefaction, and TOSCO II oil shale retorting. These findings are on the basis of both equivalent energy and the size facilities deployed in our scenarios.

- Fugitive hydrocarbon concentrations resulting from oil shale retorting, liquefaction, and natural gas production are expected to exceed the federal 3-hour standard.

- SO_2 concentrations resulting from oil shale retorting are expected to exceed the federal 3-hour and Colorado 24-hour standards.

- It is expected that 96.6- to 99.7-percent removal of particulates and 58- to 93-percent removal of SO_2 will be required for electric power plants to meet all federal and state ambient air standards.

- Facilities for producing synthetic fuels from coal can usually meet all federal and state standards except for hydrocarbons in the case of coal liquefaction.

• NON-SIGNIFICANT DETERIORATION INCREMENTS

- Even when equipped with 80-percent efficient scrubbers, electric power plants will sometimes not be able to meet Class II Non-Significant Deterioration increments.

- 96.6- to 99.7-percent removal of particulates and 58- to 93-percent removal of SO_2 is expected to be required for electric power plants to meet all Non-Significant Deterioration increments.

- SO_2 concentrations resulting from oil shale retorting are expected to exceed Class II Non-Significant Deterioration increments.

• NEW SOURCE PERFORMANCE STANDARDS

- At some sites, removing only the percentages of SO_2 and particulates required to meet New Source Performance Standards can result in violation of Ambient Air and Non-Significant Deterioration increments.

- 99.3- to 99.8-percent removal of particulates will usually be required for power plants to meet the 20-percent plume opacity New Source Performance Standard for electric power plants.

3.2.1 Introduction

Air quality impacts can vary significantly depending on the choice of technology and location. Both types of factors and impacts that result when they are combined are discussed in this section.

3.2.2 Variations by Technologies

The two technological factors that affect air quality impacts most significantly are the quantities of criteria pollutants[1] emitted[2] and labor intensiveness. In the case of electric power generation, the extent to which emission control technologies are employed greatly affects emission quantities.

A. Emissions and Control Technologies

Some emission differences among technologies are basically independent of location and are almost entirely a function of the configuration of the technology. Not only are there choices among types of conversion facilities but, in the case of electric power plants, in air pollution environmental controls as well.[3]

1. Emissions

Table 3-4 presents criteria pollutant emissions data for five conversion facilities of a size likely to be sited in the West and on an equivalent energy basis for each conversion alternative. Data for the electric power plant in Table 3-4 assumes that 99 percent of the particulates and 80 percent of the sulfur dioxide (SO_2) are removed by emissions control technologies. In general, this degree of control is required to meet ambient air standards in the eight-state study area. At several of our sites, a lower level of control than this would meet New Source Performance Standards but a higher level would be required to

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[1] "Criteria pollutants" refer to the six pollutants for which ambient air quality standards are set: sulfur dioxide, particulates, nitrogen dioxide, carbon monoxide, non-methane hydrocarbons (HC), and photochemical oxidants. Although technically only non-methane HC is covered, the more inclusive term HC is generally used. The HC limit serves as a guideline for oxidants.

[2] Very little ozone and nitrogen dioxide are emitted; rather they are formed by chemical reactions in the atmosphere.

[3] Emissions control is an integral part of the plant design for synthetic fuel technologies.

TABLE 3-4: AIR EMISSIONS FOR CONVERSION FACILITIES[a]

Conversion Facility	Particulates	SO_2	NO_x	CO	HC
Typical Size (pounds per hour)					
Power Plant [b] (3000 MWe)	[illegible]	[illegible][d]	[illegible]	[illegible]	[illegible]
Lurgi Gasification (250 MMscfd)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Synthane Gasification (250 MMscfd)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Synthoil Liquefaction (100,000 bbl/day)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOSCO II Oil Shale[c] (100,000 bbl/day)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Equivalent Energy (pounds per 10^6 Btu in product)					
Power Plant[b]					
Btu (e)	[illegible]	[illegible][d]	[illegible]	[illegible]	[illegible]
Btu (th)	[illegible]	[illegible][d]	[illegible]	[illegible]	[illegible]
Lurgi Gasification	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Synthane Gasification	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Synthoil Liquefaction	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOSCO II Oil Shale[c]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

BBL = barrels
Btu = British thermal units
(th = thermal and e = electric)
CO = carbon monoxide
HC = hydrocarbons
MMscfd = million cubic feet/day
MWe = megawatts-electric
NO_x = oxides of nitrogen
SO_2 = sulfur dioxide

[a] These numbers represent the range of emissions found in the site specific scenarios; the facilities are assumed to be operating at a full load.

[b] 99-percent particulate removal and 80-percent SO_2 removal.

[c] No range is available for TOSCO II because the process was hypothesized at only one site.

[d] Had scrubbers not been hypothesized for the power plants, these numbers would be about five times larger.

meet Non-Significant Deterioration increments for Class II areas.[1]

On the basis of both the size facility deployed in our scenarios and equivalent energy,[2] electric power plants with scrubbers emit more of four criteria pollutants (SO_2, particulates, NO_x, and carbon monoxide) than any other type of conversion facility (Table 3-4). Coal gasification plants emit less pollutants than electric plants in all categories, and synthoil liquefaction produces more hydrocarbon (HC) emissions than other coal and oil shale synfuels facilities of the size deployed in our scenarios.

The results of our first-year impact analyses indicate that fugitive HC emissions from liquid processing facilities (oil shale retorting and coal liquefaction) and from natural gas production can be expected to result in ambient HC concentrations that exceed the federal 3-hour standard of 160 micrograms per cubic meter (µg/m^3).[1] Because they are emitted at or near ground-level, the total amount of fugitive HC emitted need not be large to produce the high concentrations often associated with these facilities.[2] The highest concentrations are expected to be produced by oil shale retorting (up to 52,000 µg/m^3), followed by coal liquefaction (21,500 to 25,100 µg/m^3) and natural gas production (1,000 µg/m^3). Conventionally produced natural gas affects ambient levels of HC more than the Lurgi and Synthane coal gasification processes (which range from 14 to 38 µg/m^3).

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[1] Current Non-Significant Deterioration (NSD) requirements are based on an area classification system which divides the nation's "clean air" areas (i.e., areas where the air quality is better than that allowed by ambient air standards) into three classes. Each class permits progressively larger incremental additions (or "allowable increments") to concentrations of sulfur dioxide and particulates. Class I areas are generally pristine, such as national parks, but may include any area in which it is decided to limit growth or development. Class III areas permit deterioration to national ambient secondary standards. At present, all NSD areas are designated Class II. Procedures have been established for states (and Indian reservations) to redesignate areas as either Class I or Class III.

[2] This is the case both when emissions are taken per British thermal unit (Btu) of electrical output and per Btu of thermal input to the plant. Comparing electrical energy to energy in oil and gas can be misleading since electricity has high quality uses not possible with oil and gas (such as running motors and lighting). Hence, if electricity was used only for high quality demands, it would be worth about three times as much as thermal energy in oil and gas. Only about half of electricity is so used, however, and the remainder is used for heat, for which a direct comparison with oil and gas can be justified. Numerically, on a Btu-thermal basis, electricity is valued as the energy content of the coal which feeds the power plant. On a Btu-electrical basis, the electricity is valued as the energy content of the electrical energy is produced. In the power plant, the energy produced when measured in Btu-electrical is about 3 times less than the energy as measured in Btu-thermal. Neither measure is exactly comparable to the energy content of oil and gas. A Btu-electrical is more valuable than a Btu of oil and gas; but a Btu-thermal in the power plant case is less valuable than oil and gas made from coal.

The 100,000 barrels per day (bbl/day) oil shale plants that we analyzed will also exceed the federal 3-hour and Colorado 24-hour ambient SO_2 standards.[3] As indicated in Chapter 8, this violation is in part attributable to plume impaction on high terrain.[4]

2. The Effect of Control Technologies on Emissions from Power Plants

The extent to which SO_2 scrubbers will be used on electric power plants in the western U.S. is still unclear.[5] We expect power plants without SO_2 scrubbers to emit five times the SO_2 values indicated in Table 3-4.[6] Due to the very low sulfur content of coal at some locations, New Source Performance Standards (NSPS) could be met without scrubbers.[7] However, our analysis of impacts at these sites indicate that at least one federal ambient SO_2 standard could be violated.[1] Further, at three other sites,[2] plants equipped with scrubbers that remove only enough SO_2 to meet NSPS will exceed at least one federal and some state standards. In addition, plumes at all sites will generally not meet the 20 percent opacity standard without a high level of particulate removal (99.3-99.8 percent).

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[1] The federal 3-hour standard for ambient concentrations is measured between 6 and 9 a.m. This is the time period during the day when they are characteristically highest.

[2] Leaks in valves and fittings and from fuel oil storage tanks account for most fugitive hydrocarbon emissions.

[3] The Colorado 24-hour ambient sulfur dioxide standard is 150 micrograms per cubic meter. The predicted concentration is more than 10 times the level allowed by this standard.

[4] Plume impaction occurs when stack plumes run into elevated terrain because of limited atmospheric mixing and stable air conditions. It primarily occurs when atmospheric mixing is minimal (wind speeds less than 5 to 10 miles per hour, clear sky, pre-dawn hours).

[5] The use of scrubbers will depend on many factors including their economic impact on the cost of electricity, the development of new control technologies, and the extent to which Non-Significant Deterioration requirements are made more strict.

[6] The values in Table 3-4 assume 80-percent sulfur dioxide removal.

[7] See Chapter 6 (Kaiparowits/Escalante), 8 (Rifle), and 9 (Gillette).

3. Emission Levels and Non-Significant Deterioration Requirements

Our results indicate that coal gasification and liquefaction plants can meet all Non-Significant Deterioration (NSD) increments. However, oil shale retorts and power plants (even with scrubbers) may cause Class II increments to be exceeded locally and Class I increments to be exceeded in nearby national parks. Both oil shale developments included in our scenarios would violate all Class II SO_2 and particulate increments. Power plants also appear likely to violate Class II NSD requirements. In four of the locations,[3] power plants exceed either one or both of the Class II 24-hour particulate and SO_2 increments.

The buffer zones required to meet Class I NSD increments range in size from 5 to 75 miles.[4] By far, the largest is required for electric power plants,[5] an average of about 52 miles. Buffer zones for Lurgi, Synthane, and Synthoil are roughly equivalent, averaging from 9 to 14 miles. The restrictive standard for all conversion technologies is either the 3- or 24-hour SO_2 increment.

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[1] All the above conclusions are based on dispersion modeling results that are inherently approximate. The accuracy of the Gaussian-type dispersion models used in this study is generally accepted to be ±100 percent. However, evidence is beginning to accumulate that the models may be as accurate as ±50 percent. See Appendix A for details.

[2] See Chapters 7 (Farmington), 10 (Colstrip), and 11 (Beulah).

[3] See Chapters 6 (Kaiparowits/Escalante), 7 (Farmington), 8 (Rifle), and 11 (Beulah).

[4] Allowable increments for Class I areas apply to all new sources whether located within or outside the Class I area. This effectively establishes a buffer zone around Class I areas within which new facilities cannot be sited since pollutants from the facility must be diluted by atmospheric mixing to achieve the low concentrations allowed. The distance required for this dilution to take place determines the size of the buffer zone, which varies by facility type, size, and the effectiveness of emission controls.

[5] This assumes 80-percent sulfur dioxide and 99-percent particulate removal.

At present, buffer zones are a siting consideration only in areas where there are numerous national parks that are potentially Class I areas. If national forests are designated Class I areas, buffer zones will be a consideration throughout the eight-state area.

4. Summary

In summary, total SO_2 emissions[1] and emission densities[2] would increase at all locations in the West, with the largest increases occurring in eastern Montana and western North Dakota. When scrubbers are used on electric power plants, the plants analyzed in the six site-specific scenarios are predicted to meet federal ambient air quality standards. At the locations where scrubbers are not needed to meet New Source Performance Standards, at least one federal ambient SO_2 standard could be exceeded. Class II increments will often not be met by electric power plants and oil shale facilities.

Given the levels of development postulated in our eight-state scenario, SO_2 levels in eastern Montana and western North Dakota in the year 2000 will approach those presently found in many industrialized states (emissions exceeding 2 million pounds per year and emissions densities as high as 29 tons per year per square mile in North Dakota).[3] Assuming a SO_2-to-sulfates conversion rate of 1 percent,[1] total emissions and emission densities at these levels can cause a reduction in long range visibility and possibly constitute a health hazard.[2]

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[1] Given the typical coals used in our scenarios, electric power plants in New Mexico, Montana, and North Dakota will exceed Federal New Source Performance Standards for sulfur dioxide emissions unless scrubbers are installed.

[2] Emission densities are estimated as tons of sulfur dioxide emitted annually per square mile.

[3] See Chapter 12 for details on current emissions and densities. That chapter also describes levels of energy resource development, distribution of facilities in the eight-state study area, coal compositions, and scrubber and precipitator configurations.

B. Labor Intensiveness

The second technological factor that significantly affects air quality impacts is the labor intensiveness of a technology. Our impact analyses indicate that peak ground-level concentrations of particulates, NO_2,[3] and HC produced by energy related urban development can be higher than those produced by energy development facilities themselves.[4] For example, in all our scenarios, annual particulate concentrations from urban sources (7-30 $\mu g/m^3$) exceed those from energy facilities (0.3-1.8 $\mu g/m^3$). These high concentrations result from the release of pollutants at or near ground level in urban areas by such sources as automobiles and home heating. Total emissions of pollutants in the urban area are small in comparison to those emitted by an energy conversion or production facility; in fact, less than 10 percent of the total pounds per year emitted come from urban sources. However, because pollution from urban sources are released close to the ground, they cause high concentrations; this occurs because pollutants released near ground level experience little or no mixing and dilution, whereas pollutants released from tall stacks experience considerable mixing and dilution prior to reaching ground level.

Table 3-5 summarizes the projections from our scenarios for peak ground-level concentrations of pollutants originating from urban sources and from energy facilities in 1990. Note that the

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[1] Most estimates of sulfate formation in the plumes of coal fired power plants with particulate control use a conversion rate of 1 to 3 percent. Up to 20-percent rates have been used for oil-fired power plants. See U.S., Congress, House of Representatives, Committee on Science and Technology, Subcommittee on Environment and the Atmosphere, Review of Research Related to Sulfates in the Atmosphere, Committee Print. Washington, D.C.: Government Printing Office, 1976.

[2] Health effects are discussed in Section 3.6.

[3] The oxides of nitrogen emitted by energy facilities occur in several molecular forms, generally designated NO_x. Ambient air standards are set in terms of nitrogen dioxide (NO_2). In measuring emissions, whatever combination of NO_x occur are converted to NO_2 according to their molecular weights to allow comparison with the NO_2 standards.

[4] See section 3.4 for details on the increases in population that can be attributed to energy resource development.

TABLE 3-5: A COMPARISON OF PREDICTED PEAK GROUND-LEVEL CONCENTRATIONS OF POLLUTANTS FROM URBAN SOURCES AND ENERGY FACILITIES, 1990[a]
(micrograms per cubic meter)

Pollutant	Standard[b]	Kaiparowits		Farmington		Rifle		Gillette		Colstrip		Beulah	
		Urban	Facility	Urban	Facility	Urban	Facility	Urban	Facility	Urban	Facility	Urban	Facility
SO_2													
Annual	80	8	4.4	39	3.3	2	11	14	1.6	5	2.7	4	.4
24-hour	365	17	51	54	84	8	131	40	51	17	98	14	6.8
3-hour	1300	40	129	96	459	3	1,901	94	182	38	657	24	35
Particulates													
Annual	60	15	1.6	38	1.8	20	1.2	17	.4	10	.5	7	.3
24-hour	150	34	20	101	67	48	102	51	19	34	22	24	5.7
NO_2[c]													
Annual	100	36	11	40	6.5	4	4.4	41	4.6	39	3.6	11	1.8
HC													
3-hour	160	461	40	871	78	571	12,130	782	78	270	69	161	14

HC = hydrocarbons SO_2 = sulfur dioxide
NO_2 = nitrogen dioxide

[a] The data displayed in this table are taken from the discussions of pollutants from urban sources and from energy facilities described in Chapters 8-13. These discussions further elaborate these data and provide data points for other years (1980, 2000) and for other towns and facilities not summarized here; the data from both urban sources and facilities represent peak, not average concentrations. Since several scenarios have more than one energy facility, an effort was made to use the facility with highest peak concentrations to compare to urban sources. For each scenario, the facility used for comparison in this table was: Kaiparowits: power plant; Farmington: power plant/mine combination; Rifle: 100,000 barrels per day TOSCO II plants; Gillette: power plant/mine combination; Colstrip: power plant/mine combination; Beulah: Lurgi/plant mine.

[b] The lowest applicable ambient air quality standard is listed here. Each of the scenario chapters (8-13) lists both primary and secondary standards.

[c] Estimates of NO_2 concentrations at facilities were based on the assumption that all oxides of nitrogen (NO_x) would be converted to NO_2. For urban concentrations, it was assumed that 50 percent of the NO_x would be converted to NO_2. See the Introduction Part II for an elaboration.

[d] Not calculated.

concentrations of particulates, NO_2, and HC produced by urban sources nearly always exceed those from the energy facility.[1]

The models used to estimate air impacts also suggest that these concentrations are not likely to increase consistently as urban population increases, but rather to increase rapidly as the total urban population rises to about 15-20 thousand people and at a progressively slower rate thereafter.[2] Thus, small or new towns in the West are likely to experience a high percentage increase in ambient pollutant levels as population increases, while larger towns (such as Farmington) will experience relatively little change.[3]

C. Other Technology-Related Impacts

Other air impacts analyzed were long-range visibility, cooling tower fogging and icing, cooling tower salt deposition, fine particulates, oxidants, and weather modification. Findings in each of these areas are based on preliminary results and are mostly qualitative. None of these impacts appears to be large except for the visibility reductions which, at the sites analyzed, averaged 8 percent on an annual basis. Reductions may be substantially larger during episodic conditions. Thus, the generally excellent visibility in the region (characteristically 65-70 miles) could be restricted in the vicinity of the plants, and the plumes from many plants would be visible. Plumes can also extend long distances from a facility, allowing sulfate formation to darken the plume.

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[1] Some sulfur dioxide (SO_2) concentrations from urban sources exceed those from the energy facilities. However, annual and 24-hour concentrations of SO_2 from both urban sources and facilities are well below federal ambient standards.

[2] Projected concentrations from urban sources are derived from both emission rates and dispersion potential. The projection that concentrations increase rapidly up to a point (15-20 thousand people) and progressively slower thereafter is based on several important and debatable assumptions. First, emission rates from urban sources are assumed to be directly (or linearly) proportional to the number of people in the town. Secondly, the population densities of different-size towns are assumed to remain relatively constant. Thus, since urban emission concentrations are measured at a point in the center of town, pollution sources more than 1 or 2 miles from the center will have little effect on concentrations measured there. For towns larger than 15-20 thousand, it is assumed that new pollutant sources will be located increasingly further from the center of town and thus have only marginal impact on concentration levels.

[3] See Section 1.4 for data on labor intensiveness.

Energy development is also likely to produce smog and fogging impacts. Background HC, in combination with oxides of nitrogen in plumes, provides the potential for oxidants (smog) downwind of the plant. Fogging is common in the winter in the West, and cooling towers will exacerbate this problem downwind of plants. Due to low humidities, fogging will not be a problem during other seasons.

3.2.3 Variations in Existing Conditions

Many air quality impacts can be attributed to variations in existing conditions at different locations in the West. Many of these existing conditions are geographical or meteorological in nature, such as rugged terrain, poor dispersion potential, and the proximity of resources or sites to Class I or Class II areas. Other existing conditions affecting air quality include characteristics of the coals found in different locations, the size of communities located in the vicinity of the resource development, ambient air quality, and state air quality standards.

A. Coal Characteristics

Although low sulfur is an advantage commonly attributed to western coals, many western coals also have low heating values.[1] The sulfur content of the coals used in our analyses range from 0.5 to 1.0 percent by weight and heating values ranged from 6,950 to 11,300 Btu's per pound. As a result of these variances, sulfur emissions on a per-million Btu's basis are not necessarily low. Assuming that 100 percent of the sulfur in the coal is converted to SO_2, the Kaiparowits, Rifle, and Gillette coals meet the New Source Performance Standard of 1.2 pounds of SO_2 emitted for every 1 million Btu's of coal burned. For the other coals to meet the standard, only 52-73 percent of the sulfur could be converted to SO_2 in the boiler; that is, 27-48 percent of the sulfur would have to be retained in the ash. However, less than 80-percent conversion (greater than 20-percent sulfur retention) is unlikely.[2]

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[1] See the Introduction to Part II for the characteristics of the coal used in these analyses.

[2] One study of power plants burning North Dakota lignite found cases in which the sulfur retention rate was much greater than 20 percent; that is, less than 80 percent of the sulfur in the coal was converted to sulfur dioxide. However, on 11 of the 46 test days in the study, the 1.2 pounds per million British thermal units emission limit was exceeded anyway. The amount of sulfur retention was found to be a function of boiler design and the sulfur content of the coal. See Gronhovd, G.H., P.H. Tufte, and S.J. Selle, "Some Studies on Stack Emissions from Lignite Fired Plants." Paper presented at the 1973 Lignite Symposium, Grand Forks, North Dakota, May 9-10, 1973.

A related consideration is the variability of sulfur content among and within coal fields and within a single seam. This variation could conceivably result in some high-sulfur coal (up to 3-5 percent) being used in plants designed exclusively for low-sulfur coal. This is usually prevented by blending high- and low-sulfur coals to produce a coal feedstock with an average sulfur content capable of meeting low-sulfur requirements. Although low-sulfur coal will be used wherever possible, such use will be constrained both by coal ownership and how easily the coal can be mined.

The mining plan developed for a coal mine usually details the procedure for blending coals based on the analysis of core samples taken from several sites in the mine area. However, it is also becoming common for coal customers to require coal suppliers to guarantee a maximum sulfur content in their contracts.

B. Terrain and Dispersion Potential

Another significant existing condition influencing air quality in the eight-state area is terrain, most notably the complex terrain found in western Colorado and southern Utah. Our impact analyses suggest that the complex terrain in southern Utah can contribute to high ground-level concentrations of pollutants as a consequence of plume impaction. In northwestern Colorado, ambient levels of SO_2 are predicted to exceed the Federal ambient secondary standard (3-hour average) when the plume from the 100,000 bbl/day oil shale plant interacts with the rugged terrain features in the area. These SO_2 violations are likely to occur less than 30 percent of the time. In the Kaiparowits/Escalante area, predicted ambient levels produced by plume impaction approach but do not exceed ambient standards.[1]

At our other site-specific scenario locations, the terrain is less rugged and plume impaction does not normally occur. In these cases, increased concentrations are predicted to result from other conditions such as plume looping and limited vertical mixing.[1]

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[1] These results were obtained using a modified Gaussian air dispersion model. Although other routines, such as potential flow models, have been used to project impacts in rough terrain, no consensus exists regarding the most appropriate model. However, the modifications made in this analysis were designed to account for previous limitations of Gaussian-type models in rough terrain. See Appendix A.

Dispersion meteorology is variable over the eight-state area. By itself, poor dispersion does not cause violation of standards at any one site. However, when combined with other factors, such as complex terrain, it can exacerbate what already may be a problem.

An overview of the effect of site specific variations is presented in Table 3-6. This table shows the level of control required for power plants to meet all standards at our six sites. To meet all ambient air standards, Class II increments, and applicable state standards, 96.6-99.7 percent of the particulates and 58-93 percent of the SO_2 would have to be removed. The specific requirement depends on the site.

Due to Colorado's strict SO_2 standards, any facility located in that state will require the removal of more SO_2 than in any of the other seven states. A higher percentage of SO_2 removal is required to meet Colorado's standard than to meet Federal Class II NSD increments. State standards are also restrictive in North Dakota for both SO_2 and NO_x. Emissions from facilities located in North Dakota can meet the Federal Class II NSD SO_2 increment but not the state standards. Similarly, approximately 70-percent NO_x removal would be required to meet North Dakota standards.[2]

C. Other Site Specific Variations

Two other factors that vary by site can exacerbate air quality problems: the size of the community in which the facility is located, and the proximity of a facility to potential Class I NSD areas. As noted above, the percentage change in air quality will be greater when a facility is located in a small community than when it is located in a large town. As a result, in sparsely populated areas such as southern Utah, the change in air quality will be relatively greater even though the absolute level of ambient concentrations may be the same as in more densely populated areas.

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[1] Plume looping (i.e., when plumes rise, sink to the earth or roll in response to breezes, air currents or eddies) occurs when winds are less than 5 miles per hour and solar radiation is strong (summertime, midday, clear sky). Large thermal eddies cause plumes to roll thus transporting undiluted plume segments rapidly to ground level. Limited mixing occurs when a strong inversion exists slightly above the plume height and stops the upward mixing of the plume. The plume is constrained vertically between this "lid" and the ground.

[2] Sulfur dioxide scrubbers also remove some percentage of oxides of nitrogen, perhaps as much as 40 percent.

TABLE 3-6: EMISSION CONTROLS REQUIRED FOR POWER PLANTS TO MEET ALL STANDARDS AT EACH OF SEVEN SITES[a]

Site[b]	Percent Removal	
	SO_2	Particulates
Gillette	58	96.6
Kaiparowits[c]	61	98.1
Farmington	70	99.5
Colstrip	79	98.1
Beulah	81	98.8
Rifle	92	99.0
Escalante	93	99.7

SO_2 = sulfur dioxide

[a] All air quality standards include federal ambient and Class II increments as well as applicable state standards. State standards are restrictive only in Colorado and North Dakota.

[b] Except for Rifle, power plants are 3,000-megawatts-electric (MWe); the plant at Rifle is 1,000 MWe.

[c] Even though they are included in the same site-specific scenario, the Kaiparowits and Escalante power plants are analyzed separately.

Class I NSD areas (such as national parks) may present some problems where they are widespread or occupy large amounts of land (as in southern Utah), but very few are located in the coal regions of the Northern Great Plains. Proximity to Class I NSD areas will make development siting more difficult, particularly in the case of electric power plants where large buffer zones are required.

3.2.4 Summary of Technological and Location Factors

In combination, some technological and locational factors can cause air quality impacts to be particularly severe. These impacts can often be mitigated by choosing a different technology for the problem site, a different site for the problem technology, or an entirely different technology-site combination.

This summary identifies technology-locational combinations that cause critical air quality problems. By so doing, it also suggests combinations that could mitigate these problems. The problems that can arise because of technology-location combinations are identified in Table 3-7. The table also indicates the technology and locational factors that cause the problem. Note that nearly all the critical problems are caused by either electric power plants or oil shale retorting facilities.

In some locations in the West, New Source Performance Standards (generally the least restrictive set of federal standards for conditions in the eight-state area) cannot be met by electric power plants without scrubbers. This problem is a consequence of the heat and sulfur contents of the coal.

At most locations, Class II PSD standards will be violated by electric power plants even when scrubbers with an 80-percent efficiency for SO_2 are used. The existing ambient air quality, dispersion potential, and terrain characteristics in southern Utah, Colorado, North Dakota, and Montana make these areas particularly susceptible to the problem. To mitigate the problem, Class II PSD increments would have to be relaxed, scrubbers with a higher removal efficiency would have to be employed, or the coal would have to be exported for conversion elsewhere.

Terrain characteristics in southern Utah and western Colorado are such that regular violation of several federal or state ambient air standards will occur as a result of emission from power plants (with scrubbers) and from oil shale retorting facilities. Mitigation will require very high scrubber efficiencies or exporting the coal.

In Colorado and North Dakota, state air quality standards will determine the level of control required. Emissions from the electric power plant and oil shale facility sited at Rifle, Colorado exceed Colorado's SO_2 standards, and the electric power plant sited at Beulah, North Dakota exceeds North Dakota's SO_2 and NO_2 standards. Mitigation will require either the relaxation of state standards, the use of scrubbers with higher removal efficiencies, or exporting the coal.

Siting problems in southern Utah and western Colorado will be exacerbated by the proximity of sites to Class I PSD areas, principally national parks. The buffer zone required is greatest for electric power plants. Mitigation will require either the relaxation of Class I PSD increments, the use of scrubbers with higher efficiencies, or exporting the coal.

The labor intensity of conversion facilities, particularly the operating labor requirements of synthetic fuels facilities,

TABLE 3-7: SUMMARY OF AIR QUALITY PROBLEMS

Air Quality Problems	Combinations of Factors that Cause the Problem	
	Technological Factors	Locational Factors
Violations of Federal New Source Performance Standards as well as other standards in Farmington, Colstrip, and Beulah areas	Emissions from power plants without scrubbers	Sulfur content and heating value of the coal
Violations of Class II NSD Standards (especially in southern Utah, Colorado, North Dakota, and Montana)	Emissions from power plants with scrubbers	Existing ambient air quality, dispersion potential, terrain
Violation of ambient standards especially in southern Utah and Colorado	Emissions from power plants with scrubbers and oil shale processing facilities	Rough terrain
Requirements for strict SO_2 control in Colorado and strict SO_2 and NO_x control in North Dakota	Emissions from power plants with scrubbers and oil shale processing facilities	State air standards
Potential siting problems, especially in Utah and Colorado depending on how Class I NSD areas are defined	Emissions from conversion facilities, especially power plants, required buffer zones	Proximity to Class I areas (national parks and possibly national forests)
Larger concentrations of several pollutants produced by urban sources than by facilities. Largest increase in towns under 15,000	Labor intensiveness, especially synthetic fuels technologies	Community size

NSD = Non-Significant Deterioration NO_x = oxides of nitrogen SO_2 = sulfur dioxide results in greater ambient concentrations of particulates, nitrogen oxides, and hydrocarbons being caused by urban sources than by the energy facilities. If the community in which development takes place is small (e.g., most communities in southern Utah), the percent change in ambient air quality as a result of urban sources will be great. Mitigation may require the export of coal from these sites rather than mine-mouth conversion.

In general, this summary suggests that facilities in Wyoming, Montana, and New Mexico are likely to have the fewest air quality problems. In these states, applicable federal and state standards can be met with the least percentage removal of SO_2 and particulates by emission control technologies. But in no case can all standards be met without the use of some emission control, specifically scrubbers.

Facilities located in southern Utah and western Colorado will present the greatest problems unless removal percentages are quite high. In Colorado, this is largely due to state SO_2 standards and, to some extent, the terrain in the oil shale area of western Colorado. Southern Utah appears to have a restrictive combination of factors affecting air quality, a combination of poor dispersion potential and complex terrain that could result in frequent violation of ambient standards and Class I areas that are in close proximity to development sites.

3.2.5 Data and Research Limitations

The analysis and findings produced during the first-year effort have been limited by both data availability and research limitations. The areas of greatest data inadequacy concern trace elements and trace organic emissions from energy facilities, particularly from advanced energy facilities such as coal gasification, coal liquefaction, and oil shale retorting. The principal reason for these data inadequacies is that full-scale units of these technologies have not become operational, thus no measurements of these trace emissions have been possible.

Another area of limited data availability is atmospheric formation of nitrates and other nitrogen compounds. Research in this area is just beginning, and only preliminary results are currently available.

Data on SO_2 removal rates for low-sulfur western coals is another limitation. While it appears technically feasible to build scrubbers capable of removing very high percentages of SO_2 (e.g., 91 percent), data regarding the actual use of scrubbers on low-sulfur coal or on the economic trade-offs involved is limited.

Finally, conclusions regarding the relative concentrations of pollutants produced by urban and energy facility sources are preliminary, owing to the lack of data on urban emissions from towns under 50,000.

Suitable models were not available for predicting the impact of western energy facilities on short-term visibility, long-range transport of pollutants from tall stacks, visibility during episodic air conditions, secondary air pollutants such as oxidants and sulfates, and regional air quality. Although predictive models exist, none was considered suitable for use durin the first year of the project.[1]

3.3 WATER AVAILABILITY AND QUALITY[2]

HIGHLIGHTS

• CRITICAL FACTORS

- *Four factors that vary among technologies can significantly affect water impacts: water requirements; labor intensiveness; amount and composition of effluents from facilities and energy-related population increases; and the disruption of aquifers.*
- *Four locational factors can also significantly affect these impacts: water availability; water quality; coal characteristics; and aquifer characteristics.*

• WATER REQUIREMENTS

- *Electric power plants require more water than any other conversion technology.*
- *Lurgi requires less water than any other synfuel technology.*
- *Cooling accounts for up to 96 percent (with a median value of 80 percent) of the total water requirements of coal and oil shale conversion technologies.*

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[1] Suitability in this content refers to model requirements for complex data and resulting expense in application.

[2] The conversion technologies considered include coal-fired electric power plants, Lurgi and Synthane gasification, Synthoil liquefaction, and TOSCO II oil shale retorting. Slurry pipelines were also considered. All facilities use wet cooling and all their effluents are discharged into on-site evaporative ponds.

- Water requirements for mining and reclamation are an order of magnitude less than that required for mine-mouth conversion complexes.

- Water requirements for energy-related population increases are, on the average, one-tenth that for conversion facilities.

• WATER AVAILABILITY

- Water for energy development is less clearly available in the Colorado River Basin than in the Upper Missouri Basin; unquantified federal and Indian water rights, the legal status of unused allocated rights, and other unanswered questions make the availability of water uncertain in both basins.

- By the year 2000, a low-development scenario would require 28-52 percent of the surface water apparently available in the Upper Colorado Basin; a high-demand scenario would require 43-71 percent.

• MINIMIZING WATER REQUIREMENTS

- Water consumption by conversion facilities could be reduced by up to 77 percent if wet/dry rather than wet cooling were used.

- Water consumption varies significantly by location for the same coal conversion technology.

• EFFLUENTS

- The quantity and composition of effluents from the coal conversion plants varies with location. For a given process the quantity of waste effluents varies by a factor of four depending upon location. Effluents from gasification are almost entirely ash whereas effluents from electric power plants are comprised of approximately equal amounts of ash and sludge from flue gas desulfurization.

- The ash and sulfur content of coal are largely responsible for the site variation in the quantity of waste effluents; the highest ash coals are to be found in the Southwest.

- Outstripping all the coal conversion residuals by an order of magnitude are those from surface oil shale processing; the primary residual is the wet spent shale.

- *Discharging effluents into evaporative ponds poses a potentially significant surface and groundwater quality problem.*

3.3.1 Introduction

Factors that cause water impacts and vary by technology are: the water requirements of the technology and the associated population increase, energy facility and domestic sewage effluents, and aquifer disruption. The severity of impacts that result from these factors depends on site-specific factors such as water availability, coal characteristics, aquifer characteristics, and existing water quality. This section describes the extent to which these factors vary among technologies and sites and the extent to which these variations affect impacts. Data and research inadequacies limiting water impact analysis during the first year are also identified.

3.3.2 Variations Among Technologies

Technology-specific factors are discussed in three categories: water requirements, water effluents, and aquifer disruption.

A. Water Requirements

Water requirements are discussed under the following headings: water requirements of energy facilities, the effect of wet/dry cooling on water requirements, and the effect of labor intensity on water requirements.

1. Water Requirements of Energy Facilities

The two sets of water requirement estimates used for the energy development technologies are listed in Table 3-8. The Energy Resource Development Systems (ERDS) data are rough estimates based on a variety of government sources.[1] The Water Purification Associates (WPA) data are based on detailed engineering analyses of the technologies where the objective of the analysis was to minimize water use.[2]

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[1] White, Irvin L., et al. Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[2] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

TABLE 3-6: WATER CONSUMPTION BY TECHNOLOGY[a]

Technology	Size[d]	Water Consumed			
		ERDS[b]		WPA[c]	
		Acre-Feet Per Year	Gallons/10^6 Btu in Product	Acre-Feet Per Year	Gallons/10^6 Btu in Product
Power Generation	3,000 MWe	29,100		23,891-31,820	
Per Btu (th)[e]			31		53-56
Per Btu (e)			117		137-130
Lurgi Gasification[f]	250 MMscfd	6,110	18	5,31[illegible]-5,650	15-16
Synthane Gasification[f]	250 MMscfd	9,090	18	7,873-8,470	22-26
Synthoil Liquefaction[g]	100,000 bbl/day	17,080	26	8,230-11,780	15-19
TOSCO II Oil Shale Retort[h]	100,000 bbl/day	15,830	23	13,920	22
Slurry Pipeline[i]	25 MMtpy	16,190	15	16,170	15

bbl = barrels
Btu = British thermal units (th = thermal and e = electric)
MMtpy = million metric tons per year

MMscfd = million standard cubic feet per day
MWe = megawatts-electric

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[a] No mining, reservoir evaporation, or reclamation requirements are included in the ERDS data. WPA data include water for reclamation for only those areas with less than 10 inches annual precipitation.

[b] The ERDS or Energy Resource Development System descriptions prepared for this study will be distributed separately. They are based on: University of Oklahoma, Science and Public Policy Program. *Energy Alternatives: A Comparative Analysis*. Washington, D.C.: Government Printing Office, 1975 and Radian Corporation. *A Western Regional Energy Development Study*: Final Report, 3 vols. Austin, Tex.: Radian Corporation, 1975.

[c] Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*. Final Report for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S. Environmental Protection Agency, forthcoming.

[d] Load factors are: 70 percent for electric power; 90 percent for gasification, liquefaction, and oil shale processing; and 100 percent for slurry pipeline.

[e] Per Btu, thermal refers to the coal; per Btu, electric refers to the electricity. 35-percent efficiency is assumed. See footnote [illegible] on page 3[illegible] for a discussion of the energy value of electricity as compared to thermal energy.

[f] The heating value of the product is assumed to be 950 Btu's/standard cubic foot.

[g] The heating value of the product is assumed to be 6.29 x 10^6 Btu's/bbl.

[h] The heating value of the product is assumed to be 5.88 x 10^6 Btu's/bbl/day.

[i] The heating value of the coal is assumed to be 18,[illegible] Btu's/bbl/day.

As indicated in Table 3-8, both in terms of facility size and equivalent energy, electric power generation requires more water than any of the synthetic fuel technologies. This is true whether the energy produced is valued as thermal energy or as electricity.[1] Water requirements for Lurgi gasification, Synthoil liquefaction, and TOSCO II oil shale processing do not differ significantly. However, Synthane gasification requires 1.4 to 2.6 times more water than Lurgi gasification[2] and more than any other synthetic fuels technology. Note that minimizing water requirements in the design and operation of these facilities makes a significant difference in water consumption.[3] For example, when water consumption is minimized, Synthoil consumes half as much water as it does when consumption is not minimized.

In comparison, a surface coal mine[4] requires only 2-6 gallons of water per million Btu's of coal mined (1,200-4,000 acre-feet per year).[5] This is an order of magnitude less than conversion technologies require. Moreover, some of the required water can come from mine dewatering. In short, water requirements for exporting coal by rail are negligible in comparison to mine-mouth conversion.

2. The Effect of Wet/Dry Cooling on Water Requirements

Water for cooling represents 20-96 percent of the total water requirements of energy facilities. With the exception of oil shale retorting, cooling is the largest single water user for energy conversion technologies.[1] As indicated in Table 3-9, the use of wet/dry rather than wet cooling can reduce total requirements as much as 72 percent.[2] Using wet/dry cooling for electric power generation would result in the largest savings in terms of quantity of water saved. The wide range in water savings for Lurgi gasification is due to variations in coal moisture content among sites; unlike other technologies, Lurgi uses the water in the coal directly.[3]

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[1] For a discussion of the comparison of electrical to thermal energy, see footnote 2, p. 34.

[2] How much less depends primarily on the moisture content of the coal being used since the Lurgi process accepts wet coal and uses the moisture, although at an economic cost.

[3] Water Purification Associate's (WPA)estimates are for the process design that would minimize water up to the point where minimizing water use would increase economic cost. It might be technologically feasible to reduce water requirements even further. The WPA report itself should be consulted for a description of how estimates were calculated.

[4] This assumes that the mine is sized to supply one of these technologies and that water is used for dust suppression and reclamation.

[5] White, Irvin L., et al. *Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development*. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

3. The Effect of Labor Intensity on Water Requirements

Table 3-10 gives estimates of the additional water required by the population increases associated with facility construction and operation.[4] While this water demand averages an order of magnitude lower than demands for facilities, it is not insignificant. Treatment and distribution systems will be required to supply the water. In the case of a technology such as gasification, where water requirements by the population during peak construction are 4.5 times that required during operation, overbuilding treatment and distribution systems for the construction work force is a potential problem.

Water for domestic use in small communities and rural areas is nearly always obtained from groundwater. In conjunction with withdrawals for mine dewatering and agricultural purposes, aquifer depletion is a potential problem.

B. Water Effluents

Water effluents from energy facilities and population increases are discussed below.

1. Effluents from Energy Facilities

The effluents removed as wet- and dry-solids are listed in Table 3-11 for each technology. Effluents from oil shale retorting are the largest: 111,800 tons of wet-solids and 97,200 tons of dry-solids per day, most of which is spent shale. Effluents from coal synfuels facilities do not differ significantly in amount, but they do differ in composition. An electric power plant produces nearly equal amounts of both ash and flue gas desulfurization sludge, whereas effluents from coal gasification are almost entirely ash.

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[1] Spent shale disposal is the largest consumer of water for oil shale processing.

[2] However, the dollar cost of cooling could increase.

[3] The implications of this in terms of energy efficiency are discussed below.

[4] Data on the labor intensities of technologies are presented in Section 3.4.

TABLE 3-4: WATER USE REDUCTION USING WET/DRY COOLING[a]

Technology	Size	Fraction of Water Use for Cooling (%)[b]	Maximum Water Use Reduction Using Wet/Dry Cooling	
			%	Acre-Feet per Year[c]
Power Generation	3,000 MWe	80-91	60-68	16,230-17,940
Lurgi Gasification	250 MMscfd	53-86	40-72	2,230-2,510
Synthane Gasification	250 MMscfd	65-70	49-53	3,840-4,220
Synthoil Liquefaction	100,000 bbl/day	67-87	50-65	5,080-6,550
TOSCO II Oil Shale Retort	100,000 bbl/day	22	17	2,170

bbl = barrels

MMscfd = million standard cubic feet per day

MWe = megawatts-electric

[a] Total water use and fraction used for cooling are based upon Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming. The range in values for these data is due principally to site specific differences.

[b] Power generation load factor is 70 percent; for synthetic fuels, 90 percent. This includes water use in mining.

[c] Range in amount of water saved is due to site-specific variations.

TABLE 3-10: WATER REQUIREMENTS ASSOCIATED WITH POPULATION INCREASES[a]

	Water Requirements (acre-ft/yr)[b]	
Technology	Peak Construction	Operation
Coal		
Surface Mine	71	123
Underground Mine	275	1,490
Gasification	1,570	350
Liquefaction	1,750	1,800
Power Plant	853	260
Oil Shale		
Surface Mine	239	588
Underground Mine	239	694
Retort and Processing	900	382

[a] Assumes 150 gallons per capita per day, a multiplier of 2 to account for added service personnel during construction, and a multiplier of 3.5 to account for families and service personnel during operation. Labor intensities are taken from Section 3.4.

[b] To convert acre-ft/year to gallons per day, multiply by 893.

In no case is wastewater to be discharged directly into surface or groundwater systems; wastewater will be treated and recycled on-site. Wet- and dry-solids from coal conversion facilities are discharged into on-site evaporative holding ponds. Spent shale is dumped into ravines.[1] As a result, water quality problems from effluent disposal do not arise from direct discharge but from indirect runoff to surface water and seepage to groundwater. Runoff from spent shale and water leaching through the shale represent major potential water quality problems, particularly from spent shale dumped into ravines. Total quantities are large, and thus the potential for salt contamination is great.

In the case of effluents from coal conversion technologies, the actual amounts do not vary greatly, but the content of power plant effluent and synthetic fuels from coal effluent is

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[1] Under the provisions of the Federal Water Pollution Control Act Amendments of 1972, §§ 301, 402; 33 U.S.C.A. §§ 1311, 1342 (Supp. 1976), a permit may be required for this.

TABLE 3-11: LIQUID EFFLUENTS FROM TECHNOLOGIES

Technology	Size	Wet-Solids Tons/Day[b]	Pounds/10^6 Btu in Product	Dry-Solids Tons/Day[b]	Pounds/10^6 Btu in Product
Power Generation[c]	3,000 MWe 70-% L.F.	3,140-14,510	(e) 33-152 (th) 11-52	1,820-8,850	(e) 19-103 (th) 6-35
Lurgi Gasification[d]	250 MMscfd 90-% L.F.	1,960-8,220	18-77	1,380-6,130	13-57
Synthane Gasification[d]	250 MMscfd 90-% L.F.	1,950-7,780	18-73	1,390-6,010	13-56
Synthoil Liquefaction[e]	100,000 bbl/day 90-% L.F.	3,380-14,540	12-51	2,540-11,140	9-39
TOSCO II Oil Shale Retort[f]	100,000 bbl/day 90-% L.F.	111,825	442	97,250	384

bbl = barrels
Btu = British thermal unit
L.F. = load factor
MMscfd = million standard cubic feet per day
MWe = megawatts-electric

[a] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[b] The range of values is that found at the six sites analyzed.

[c] Per Btu (th) refers to the coal; per Btu (e) refers to the electricity. 33-percent efficiency is assumed. See footnote 2 on p. 36 for a discussion of the energy value of electricity as compared to thermal energy.

[d] Assumed heating value of product to be 950 Btu's per cubic foot.

[e] Assumed heating value of product to be 6.29×10^6 Btu's/bbl/day.

[f] Assumed heating value of product to be 5.88×10^6 Btu's/bbl/day.

substantially different.[1] If accumulations of wet-solids containing heavy metals, trace elements, and complex aromatic hydrocarbons are released accidently, they could produce acute effects in local surface waters.[2] The quantities involved are quite large; based on the data in Table 3-11, 12.6-101.6 million tons of solids will accumulate over 25 years from just one facility at one site.

In addition to berm failures that may allow pollution of surface waters, seepage from holding ponds can contaminate groundwater aquifers. The degree of contamination depends on the composition of materials in the ponds, holding pond design, liner design, pond management techniques, and the characteristics of nearby aquifers and of the soil overlaying the aquifer. In turn, contaminated aquifers may introduce pollutants into local springs, seeps, and streams. The quality of water in a polluted surface stream will usually improve dramatically within 1-2 years after pollution sources are eliminated; however, polluted aquifers require much longer periods (depending on local geologic and soil conditions) to cleanse themselves.[3]

The disposal of effluents from scrubbing or ash removal is regulated under the Federal Water Pollution Control Act Amendments (FWPCA) of 1972.[4] Groundwater quality is regulated under state laws in Colorado and New Mexico and, if it is used as a source of drinking water, under the Safe Drinking Water Act of 1974.[5] State solid waste disposal laws and regulations may also apply to on-site evaporative holding ponds. As noted earlier, the FWPCA may also apply to the disposal of spent shale.

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[1] Actual concentrations of various heavy metals and trace elements are scheduled for analysis during the second year of this study.

[2] Holding pond berm design must be site-specific, and failures are common in areas where previous design experience is not available. See Smith, E.S. "Tailings Disposal--Failures and Lessons," in Aplin, C.L. and G.O. Argall, eds. *Tailing Disposal Today*. San Francisco, Calif.: Miller-Freeman, 1973, p. 358.

[3] Pettyjohn, Wayne A., ed. *Water Quality in a Stressed Environment*. Minneapolis, Minn.: Burgess, 1972.

[4] Federal Water Pollution Control Act Amendments of 1972, §§ 1311, 1342 (Supp. 1976).

[5] Safe Drinking Water Act of 1974, §§ 1424, 42 U.S.C.A. §§ 300h-3.

2. Effluents from Population Increases

The population increases associated with energy development will impose increased demands on wastewater treatment facilities. Table 3-10 gives the water demand of population increases. Assuming that half of the water used must later be treated in a sewage treatment plant,[1] sewage treatment plants capable of treating 0.03-0.8 million gallons per day (depending on the technology) will be required to serve the additional population. The total solids content of raw domestic sewage ranges from 500 to 1,000 milligrams per liter,[2] so that the wet-solids generated by population increases range from 0.06 to 1.3 tons per day (depending on the technology and solids content of the sewage). This is disposed of as sludge; it can either be buried in a landfill, used as a soil conditioner, or fermented to produce methane. These quantities are at least one thousand times less than the solids generated by energy facilities. As a result, the water quality problem associated with population increases is not one of the quantity of the wastes generated but of providing adequate treatment facilities.

Even in the quantities projected, untreated or poorly treated effluents can cause degradation in surface waters. Treatment facilities in many communities in the eight-state area are already finding it difficult to meet the 1977 federal and state effluent standards. When the need for sewage treatment is higher during the construction phase of a facility and power plant, it may be impractical to build sewage treatment plants to serve peak construction work forces since they would be underutilized later.

C. Aquifer Disruption

Underground and surface coal, oil shale, and uranium mining can produce both surface and groundwater impacts. Underground and surface mines intercept groundwater aquifers, requiring mine dewatering operations that may deplete aquifers and, in some cases, create an excess water disposal problem.[3] In the area near Rifle, the oil shale being mined is in an aquifer that supplies

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[1] In urban areas, the percentage of water use which must later be treated as sewage is 75-80 percent; we have assumed 50 percent since some of this population will be rural and served by septic tanks.

[2] P.H. McGauhey. Engineering Management of Water Quality. New York, N.Y.: McGraw-Hill, 1968.

[3] Sometimes the water obtained from dewatering operations can be used to supply water for mining, reclamation, and facility needs.

Piceance Creek. Mine dewatering could reduce the base flow of Piceance Creek to 0 (see Section 8.3).

3.3.3 Variations in Existing Conditions

Existing conditions at individual sites and for the region as a whole will affect the type and degree of water impacts. The most important variables are the quantity, quality, and accessibility of water, the characteristics of the energy resource, particularly coal, and the climatic conditions. Other, less important variables will also be identified.

A. Water Availability

Water availability estimates and the water requirements for energy development are shown in Table 3-12.[1] As indicated in the table, by 2000 water requirements for the Low Demand Case[2] (1 gasification plant, 1 slurry pipeline, 3 power plants, and 35 oil shale facilities) would require 28-52 percent of the surface water available in the Upper Colorado River Basin. Water requirements for the Low Nuclear Availability Case (2 gasification plants, 10 power plants, and 41 oil shale facilities) constitute 47-71 percent of the water available. These percentage ranges do not include water required by the added population since domestic water often comes from groundwater supplies.

Water availability does not appear to be a problem in the Upper Missouri River Basin as a whole; the water not already allocated is well in excess of anticipated requirements (Table 3-12). However, water supplies may be inadequate in parts of the Upper Missouri River Basin; for example, demands on the Yellowstone River subbasin are substantial. Moreover, much of the resource development will occur in areas well away from surface water supplies. If surface water is used to supply development in these areas, long pipelines will have to be constructed. In addition, if water demands for energy development are as high as 1 million-acre feet per year (the Low Demand Case), the navigation season on the Lower Missouri may be reduced. Available data indicate that water for the "normal" 8-month navigation season would be adequate in 24 of the 75 years analyzed.

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[1] Both estimates are questionable, availability estimates because of inadequate data and unresolved water rights and allocation questions, and requirements estimates because of inadequate data, particularly for synfuel technologies that have not been deployed on a commercial scale.

[2] See Section 3.1 and chapter 12 for a definition of the three demand cases.

TABLE 3-12: WATER AVAILABILITY AND WATER DEMAND
(acre-feet per year)

	Upper Colorado River Basin	Upper Missouri River Basin
Surface Water Availability[a]	1,540,000-2,090,000	19,880,000
Water use by the Regional Scenario in the year 2000[b] assuming nominal consumption[c]		
Conversion facilities	754,163-1,036,693	993,542-1,811,636
Population increases	44,550-56,870	60,370-98,900
Total	798,713-1,093,563	1,053,912-1,910,536
Water use by the Regional Scenario in the year 2000[b] assuming water use minimization[d]		
Conversion facilities	536,172-836,381	766,984-1,486,942
Population increases	44,550-56,870	60,370-98,900
Total	580,722-891,251	827,354-1,585,842

[a] Not allocated as of 1975, these are estimates only

[b] See Chapter 12 for a definition of these scenarios, the range in values represents the low demand and low nuclear availability cases.

[c] White, Irvin L., *et al.* *Energy Resource Development Systems for a Technology Assessment of Western Energy Resource Development.* Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[d] Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

The number of years when there would be no navigation season would increase from 0 at present to about 11 out of 75 years.[1]

A great deal of uncertainty also exists with regard to water rights in the Upper Missouri River Basin. These uncertainties appear likely to be less significant than in the Upper Colorado River Basin because a greater excess flow is available. However, allocations in the Yellowstone River Basin are currently under review, and the Montana Fish and Game Department and Water Quality Bureau have applied for instream flow allocations which, if granted, would curtail major diversions in Montana for either energy or agricultural use elsewhere. Agricultural demands, particularly for irrigation, are also expected to increase in the future.

The possibility of obtaining groundwater for both energy facilities as well as increased populations is also site-specific. The Upper Colorado has less groundwater available than does the Upper Missouri. In both basins, only a part of the water requirements of conversion facilities could be met by groundwater.

The most important aquifers in the Upper Colorado River Basin are in alluvial deposits along rivers and streams. These aquifers are recharged at a rate of 4 million acre-feet per year (twice the water available from surface streams) and store a total of 115 million acre-feet at a depth of less than 100 feet.[2] Greater quantities occur in deeper reservoirs. While the use of some part of the 4 million acre-feet per year recharge rate would not constitute aquifer mining, it would affect the streams which themselves depend on groundwater to maintain low flows. Nevertheless, groundwater is a potential source for energy development in the Upper Colorado that has not been examined closely.

There are also numerous aquifers in the Upper Missouri River Basin. A total of 860 million acre-feet is estimated to be stored in the upper 1,000 feet of rock in the basin.[3] However, withdrawal rates are often constrained by low permeability. The Madison aquifer is the most likely source of water for conversion facilities; however, its use will be expensive because it is deeply buried in most areas within the basin (7,500 feet at Colstrip).

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[1] U.S., Army, Corps of Engineers, Missouri River Division, Reservoir Control Center. *Missouri River Main Stem Reservoirs Long Range Regulation Studies*, Series 1-74. Omaha, Nebr.: Corps of Engineers, 1974.

[2] Price, Don, and Ted Arnow. *Summary Appraisals of the Nation's Ground-Water Resources--Upper Colorado Region*, U.S. Geological Survey Professional Paper 813-C. Washington, D.C.: Government Printing Office, 1974.

[3] Missouri Basin Inter-Agency Committee. *The Missouri River Basin Comprehensive Framework Study*, 7 Vols. Denver, Colo.: U.S., Department of the Interior, Bureau of Land Management, 1971.

B. The Quality of Available Water

Table 3-13 gives an indication of water quality in the Upper Colorado and Upper Missouri River Basins. Only total dissolved solids are included because this is the variable that most affects pretreatment for use by energy facilities or populations. Other water quality parameters can be important locally. As Table 3-13 indicates, there is little difference in the quality of surface water in the two basins. For the six sites studied, the White River near Rifle had the lowest total dissolved solids (181 milligrams per liter),(mg/ℓ), while Lake Powell near Kaiparowits had the highest (475-677 mg/ℓ).

Groundwater is normally higher in dissolved solids than surface water but concentrations can vary considerably. Quality is best close to the recharge site. Because recharge sites are usually at higher elevations in the mountains, quality generally decreases as elevation decreases.

TABLE 3-13: TOTAL DISSOLVED SOLIDS IN SURFACE AND GROUNDWATER (milligrams per liter)

Basin	Surface Water	Groundwater
Upper Colorado River Basin		1,000-40,000
Green River	307-1,688	
Upper Mainstem	207-621	
San Juan	159-447	
Upper Colorado River Region Outlet	558	
Upper Missouri River		
Bighorn[a]	585	
Tongue[a]	380	
Powder[a]	1,425	
Yellowstone[a]	525	
Knife[a]	970	
Missouri Mainstem[a]	440	
Madison Aquifer		
Montana		500-1,000
North Dakota		1,000-10,000

[a] Measured in the Fort Union Coal Region.

The Environmental Protection Agency National Interim Primary Drinking Water Regulations do not specify a maximum level for dissolved solids. The U.S. Geological Survey Classification System calls water fresh if the dissolved solids content is less than 1000 mg/ℓ; water is considered suitable for livestock if dissolved solids are less than 2,500 mg/ℓ.

C. Coal Characteristics and Climate

The coal characteristics at a site determine the quantity of wet solids in the effluent. In general, the coal characteristics have only a small effect on process water requirements except for the Lurgi process where coal moisture is important. Climatic conditions principally affect cooling water requirements and thus can have a large effect on total plant water consumption.

1. Water Requirements

Table 3-14 summarizes water requirements by site. The data indicate that water requirements for facilities in the Northern Great Plains (Beulah, Colstrip, and Gillette) are less than those in the Four Corners Area (Navajo/Farmington and Kaiparowits/Escalante). Water requirements at Beulah are least, averaging 22 percent lower than those at Navajo/Farmington. A Lurgi gasification facility at Beulah will use 42 percent less water than at Farmington.

The moisture content of the coal is the principal cause of these site variations in the case of synthetic fuels. Lurgi makes direct use of the water derived from the coal, thus accounting for the large variations in this process's water use by site; for other synthetic fuel processes, the water in the coal is assumed to be lost. The moisture content of coals at the six sites studied range from 13 percent at Rifle to 36 percent at Beulah.

Variations in the water requirements among sites for electric power generation result from two factors. The first factor consists of differences in flue gas desulfurization water requirements (due to differences in the sulfur content of coal). The second factor, consists of differences in the average temperature and humidity at each site; the hotter and more humid the air, the less cooling water it can absorb via evaporation.

2. Water Effluents

The ash and sulfur content of coal are largely responsible for site variations in quantities of effluent. At the six sites studied, coal ash content ranges from 5 percent at Rifle to 19 percent at Navajo/Farmington, and sulfur content ranges from 0.5 percent at Kaiparowits/Escalante to 1.0 percent at Colstrip.

TABLE 3-24: WATER REQUIREMENTS FOR EACH TECHNOLOGY BY SITE[a]

Site	Water Requirements[b] (1,000 acre-ft/yr)					
	Electric Power Generation	Lurgi	Synthane	Synthoil	TOSCO II	Slurry Pipeline
Kaiparowits/Escalante	29.82	NC	NC	NC	NC	NC
Navajo/Farmington	29.21	5.64	8.67	11.75	NC	NC
Rifle	28.47	NC	NC	NC	12.92	NC
Gillette	25.84	4.21	7.78	9.23	NC	19.17
Colstrip	26.66	4.62	7.81	10.39	NC	NC
Beulah	23.88	3.31	7.67	10.04	NC	NC

acre-ft/yr = acre-feet per year.
NC = not considered.

[a] Water Purification Associates. _Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States_, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[b] For a 3,000 megawatt-electric power plant at 70-percent load factor, for 250 million cubic feet per day gasification facilities at 90-percent load factor, 100,000 barrels per day coal liquefaction and oil shale processing facilities at 90-percent load factor and a 25 million tons per year slurry pipeline at 100-percent load factor.

coal with a high ash content will produce larger bottom or fly ash effluent streams, and coal with a high sulfur content will produce larger quantities of scrubber sludge effluent.

Table 3-15 indicates how the quantity of wet-solids effluent varies by site. For all coal to fuel and power generating processes, the largest variation between sites is more than a factor of four, with a range at Navajo/Farmington of 2.8-5.3 million tons per year and a corresponding range at Gillette of 0.7-1.3 million tons per year. The large quantity of effluent at Navajo/Farmington is associated with the high ash content of the coal (19 percent). Coal at Rifle has the lowest ash content (5 percent), and power generation there results in the smallest amount of wet-solids, five times less than at Navajo/Farmington.

The trace element composition of effluent streams is largely a function of the trace elements present in the coal. The extent to which these vary by site or region in the West is largely unknown.

D. Other Variables

Other factors that vary by site and affect water impacts are the water requirements of reclamation and the soil and aquifer characteristics at a site. Water requirements for reclamation vary primarily as a function of climate and coal seam thickness. These requirements are expected to be highest in the arid Southwest where rainfall is smallest, particularly during the summer growing season, and where coal seams are generally thinner (10.3 feet at Kaiparowits/Escalante).[1]

Soil and aquifer characteristics are important to the fate of effluents. Those characteristics vary widely both regionally and locally; thus, they are particularly important when locating a disposal pond. Low soil permeability (as in clay) is desirable to prevent seepage of effluents. Conversely, higher permeability (as in loamy soils) is desirable in septic tank drain fields to provide higher capacity and better filtration of sewage effluents.

3.3.4 Summary of Technological and Site-Specific Factors

Some technology-related problems, in combination with certain site characteristics, cause water impacts to be particularly severe. These severe impacts can often be mitigated by choosing a different technology for the problem site, a different site for the problem technology, or an entirely different technology-site combination. Table 3-16 lists the problems that can arise because of technology-site combinations and indicates what technology- and site-related factors cause what problems.

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[1] Reclamation potential is discussed in Section 3.5.

TABLE 3-15: WET SOLIDS RESIDUALS FOR EACH TECHNOLOGY BY SITE[a]

Site	Wet-Solids[b] (MMtpy)					
	Electric Power Generation	Lurgi	Synthane	Synthoil	TOSCO II	Slurry Pipeline
Kaiparowits/Escalante	5.30	NC	NC	NC	NC	NC
Navajo/Farmington	5.08	3.90	2.84	5.31	NC	NC
Rifle	1.34	NC	NC	NC	40.01	NC
Gillette	1.32	0.72	0.71	1.23	NC	-
Colstrip	3.01	1.27	1.12	2.07	NC	NC
Beulah	2.65	1.20	1.08	2.08	NC	NC

MMtpy = million tons per year
NC = not considered

[a] Water Purification Associates. Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

[b] For a 3,000 megawatt-electric power plant at 70-percent load factor, for 250-million cubic feet per day gasification facilities at 90-percent load factor, 100 barrels per day coal liquefaction and oil shale processing facilities at 90-percent load factor and a 25-million tons per year slurry pipeline at 100-percent load factor.

TABLE 3-16: SUMMARY OF WATER PROBLEMS

Water Problems	Combinations of Factors that Cause the Problem	
	Technological Factors	Locational Factors
Severe water shortages generating water rights conflicts	Conversion facilities (especially electric power generation)	Upper Colorado River Basin (especially New Mexico), moisture content of the coal, climate
Groundwater contamination from facility effluent	Conversion facilities (especially oil shale processing)	Soil permeability and aquifer depth
Surface water contamination from domestic sewage	Electric power generation, coal gasification	Small communities or others with treatment facilities operating near capacity.
Aquifer disruption	Mining	Location of the aquifer relative to the seam

Water for energy conversion facilities is apparently less available in the Upper Colorado River Basin than in the Upper Missouri River Basin. Water for energy development in New Mexico is particularly limited. Since electric power generation requires more water than any other conversion technology, a worst-case combination in terms of water impacts is to site an electric power plant in New Mexico. Further, the generally low moisture content of southwestern coals and the hot climate means that energy conversion will require more water in that area.

Groundwater availability for energy conversion is highly uncertain in both the Upper Colorado and Upper Missouri River Basins. There is undoubtedly more groundwater in the Upper Missouri River Basin than in the Upper Colorado River Basin, but the amounts in the Upper Colorado cannot be ignored as a source for energy development. Mitigation of water use shortages and conflicts may require the use of wet/dry cooling (particularly in the Southwest) or the export of coal from the Upper Colorado River Basin.

If groundwater contamination through seepage from evaporative holding ponds (which retain the liquid wastes from power generation and coal-synthetic fuels) is to be prevented, careful siting of these ponds will be required. Prevention of groundwater contamination via seepage through spent shale remains an unsolved problem since spent shale will not be held in lined ponds. In the vicinity of evaporative holding ponds and spent shale disposal sites, soil permeability should be low and aquifers at great depth. The longer any seepage remains in the soil prior to migrating to an aquifer, the more contaminants that can be absorbed by the soil. Given the uncertainties surrounding the probable increase in seepage rates over time, mitigation calls for strict design standards for evaporative holding ponds and new approaches to spent shale disposal.

Surface water contamination from untreated or poorly treated domestic sewage is a potential problem wherever and whenever population increases outstrip the capacity of sewage treatment plants. The problem can be critical when construction workforces are in excess of operating workforces, as in the case for an electric power plant and coal gasification plant. Small communities, where the capacity of sewage treatment facilities is limited and effluent quality is marginal, are particularly susceptible to sewage overloads. Mitigation calls for policies that require sewage treatment expansion prior to the construction of a conversion facility or for temporary sewage treatment arrangements during the construction phase.

Aquifer disruption, with concomitant reduction in groundwater flow to surface streams, is a potential problem wherever mining takes place within an aquifer. Mitigation may require reclamation of the mined areas as mining proceeds (rather than reclamation after the life of the mine). The problem will be lessened to the extent that groundwater flow is reestablished and the length of time the flow is disrupted kept to a minimum.

3.3.5 Data and Research Adequacy

The water impact analyses conducted to date confirm what others have found, that the assessment of the water impacts of western energy resource development are severely handicapped by the high degree of uncertainty about water availability. While this handicap is discussed most frequently in the context of surface water, primarily in the Upper Colorado River Basin, the lack of knowledge about groundwater is a handicap as well. (See Chapters 4 and Section 14.2.)

At present, uncertainties concerning the impacts of groundwater on energy development and vice-versa are primarily due to the lack of an adequate data base. The location of aquifers, their depth, their rate of recharge, and the quantity and quality of the available water are all highly uncertain. As indicated in Chapters 12 and 14, rights questions are now being raised with regard to groundwater. Also, as groundwater and surface water interrelationships receive more attention, the questions and issues that have previously been associated only with surface water are also being raised in connection with groundwater. The effect that using municipal wastewater for irrigation will have on surface and groundwater quality and recharge rates is still being debated.

Information is inadequate to assess problems that could occur as a result of discharging effluents into on-site evaporative ponds. These effluents, including trace elements, have not been quantified, and any interactions that could occur in the region are unknown. For much of the eight-state study area, construction and operating practices for holding ponds are not well developed; therefore, it is difficult to estimate a failure rate for them.

Finally, the water needs of each of the technologies need to be improved with data from commercial operations under these environmental conditions and with the various types of coal found in the western region. These data are not currently available for any technology except electric power generation. Information is also needed on the extent to which water requirements can be minimized and the changes in the quantity and quality of effluents which result when alternative water treatment technologies are used.

3.4 SOCIAL, ECONOMIC, AND POLITICAL

HIGHLIGHTS

- **CRITICAL FACTORS**
  - Three technological factors can significantly affect the social, economic, and political impacts of energy development: labor intensity, capital intensity, and scheduling.
  - Six locational factors can also significantly affect these impacts: community size and location, capabilities of existing institutions, historical out-migration, characteristics of the local labor force, local financial conditions, and the culture and lifestyles of an area.
- **LABOR INTENSITY**
  - The requirements for housing, schools, and other public and private facilities and services are largely determined by the labor intensity of the energy development technologies deployed.
  - On an equivalent energy basis, labor requirements for coal gasification are greater than for the other conversion technologies considered; oil shale retorting and electric power generation require the least (on a per-Btu thermal basis).
  - Large differences between construction and operating labor requirements exacerbate population-related impacts. In such cases, services and facilities will be inadequate during the construction phase or overbuilt for the operations phase.
  - Among conversion technologies, coal gasification has the largest difference between construction and operation phase labor requirements; coal liquefaction has the smallest.
- **SCHEDULING**
  - The scheduling of the construction of multiple facilities within the same area can either exacerbate or minimize the effects of differences in construction and operating phase labor requirements.

- **CAPITAL INTENSITY**
  - *The capital intensity of a technology is an indicator of potential tax revenue and personal income increases.*
  - *All conversion technologies are capital intensive and can produce public revenues in excess of added public expenditure requirements over the long term.*
  - *Property taxes are generally not available during construction when demands on government are generally greatest.*
- **JURISDICTIONAL DISTRIBUTION**
  - *Increases in revenues will often go to county governments while it is the towns that have to absorb most of the population increases and meet most of the facilities and services needs.*
- **COMMUNITY CHARACTERISTICS**
  - *Rural areas and small communities will experience more dramatic "boom" type impacts and require longer lead times to provide adequate services and facilities.*
  - *Isolated communities are more likely to experience severe "boom" type impacts than will any one community in an area where there are numerous towns in the vicinity of an energy development.*
  - *Population impacts will be less in communities where the local labor force can meet some of the labor needs of energy development.*

3.4.1 Introduction

Most of the social, economic, and political impacts expected to occur as a consequence of western energy development stem directly from large and rapid population increases. The magnitude of the population increase that can be expected is related to the labor force required by the energy resource development technologies being used and the size of the development. The magnitude and seriousness of the resulting social, economic, and political impacts are related to the conditions existing in the area at the time the development takes place.

3.4.2 Variations Among Technologies

Features of energy technologies that can have significant impacts on social, economic, and political conditions are labor requirements, scheduling, and capital intensity. These features help determine the pace and extent of migration to an area, as well as the financial and managerial capability of local governments to provide services and capital facilities.

A. Labor Requirements

Labor-intensive energy resource developments will attract a large number of people to jobs in development areas and magnify social, economic, and political impacts. A growth rate of more than 7 percent will double population in less than 10 years and tend to produce serious dislocating impacts.[1]

Further, labor forces will vary during the construction phase and between the construction and operation phases of an energy facility. One overall labor indicator that facilitates a comparison of technologies is the ratio of peak construction personnel to operational personnel requirements (Table 3-17). A high ratio indicates that more workers are needed during construction than during operation. This results in excess requirements for housing, schools, and other public and private services during the construction phase and increases the likelihood that services and facilities will be inadequate and that quality of life will decline locally. Coal gasification, electric power generation, and oil shale retorting exhibit the highest ratios, indicating that demands on local communities will be large during construction and much smaller during operation. Conversely, coal, uranium, and oil shale mining exhibit an inverse relationship.

Obviously, if an energy resource development requires a substantially greater labor force during construction, a local building program designed to meet construction population needs will result in an excess of permanent facilities over the long term. Likewise, when the construction phase of a development lasts for several years, long-term facility needs may also be

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[1] See, for example, Ford, Andrew. *Summary Description of the BOOM1 Model*. Los Alamos, N.M.: Los Alamos Scientific Laboratory, 1976; and University of Denver, Research Institute. *The Social, Economic, and Land Use Impacts of a Fort Union Coal Processing Complex*. Final Report, for U.S., Energy Research and Development Administration. Springfield, Va.: National Technical Information Service, 1975. FE-1526.

TABLE 3-17: CONSTRUCTION AND OPERATIONAL MANPOWER REQUIREMENTS FOR ENERGY FACILITIES

Facility	Manpower Requirements[a] (Man-Years)			
	Construction		Operation	Ratio[b]
	Duration (Years)	Peak Employment		
Coal				
Surface Mine	5	210	550	.4
Underground Mine	6	820	2,530	.3
Gasification	5	4,800	590	8.1
Liquefaction	7	5,220	3,060[d]	1.7
Power Plant	8	2,540	440	5.8
Oil Shale				
Surface Mine	4	710	663	1.1
Underground Mine	4	710	1,180	.6
Retort and Processing	6	2,680	650	4.1
Crude Oil Production[c]	7	3,920	2,050	1.9
Natural Gas Production[c]	5	1,700	790	2.2
Uranium				
Open Pit Mine	5	80	180	.4
Underground Mine	5	440	840	.5
Milling	3	90	110	.8

[a] The listed requirements are for the typical size facilities shown in Table 3-6. Data are from Carasso, M., *et al*. *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975, vol. 1, pp. 6-30 to 6-31 and involve uncertainties -10 to +20 percent; data for developing technologies (coal liquefaction, gasification, and oil shale processing) involve uncertainties of -30 to +75 percent.

[b] The ratio expressed is Construction/Operation. The larger the ratio, the greater the employment decline when construction ends.

[c] Includes exploration (including dry holes), development, and production. See Carasso, *et al*. *Energy Supply Model*, pp. 6-7 to 6-15.

[d] *Ibid*. This figure is among those with the greatest uncertainty. In addition, economics of scale are not incorporated into coal liquefaction facilities over the 21,700 barrels (bbl) per day plant assumed by Bechtel.

overestimated.[1] On the other hand, a building program designed primarily for the population size expected over the long-term may result in inadequate facilities for most of the construction period. In such a case, some facilities problems can be alleviated rather easily, but others cannot. For example, schools can schedule double sessions and/or erect temporary facilities to accommodate the excess of pupils, but medical facilities may become overloaded and attracting additional medical personnel to the area may be difficult. Most doctors would probably be unwilling to establish practices in these areas, knowing that they might be forced to relocate within a few years. Similarly, local landlords and investors would not be likely to build adequate housing for the short-term population, knowing that the demand for housing will drop markedly within a few years.

A second indicator of labor intensity is the sum of peak construction and operation manpower requirements (Table 3-18). This indicator suggests that coal liquefaction, crude oil production, and coal gasification are the most labor-intensive technologies for the energy outputs of the facilities assumed in our scenarios. However, this ordering changes somewhat when uniform energy output of 10^{15} Btu's per year is assumed; under this assumption, coal gasification and liquefaction require the greatest amount of labor. The labor intensity of electric power generation depends on how the energy produced is measured. If measured as output electricity, its labor intensity is similar to that for coal synthetic fuels; if measured as thermal input, its labor intensity is similar to that of an underground coal mine. By both measures, uranium mining and milling and surface coal mining are low in overall manpower requirements.

Larger work forces contribute both directly and indirectly to population increases to communities near energy development sites. Larger populations mean larger demands for housing, public facilities, and public and private services, as well as greater stress on roads and streets and law enforcement agencies. Thus, any large and rapid increase in population creates a substantial demand for additional services and facilities from local governments.

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[1] John S. Gilmore's descriptions of boom and bust have included several examples. One of these is Kenai, Alaska, where the response to the construction of a petroleum development complex resulted in excess housing, retail services and public facilities. See Gilmore, John S., Keith D. Moore, and Diane M. Hammond. *Synthesis and Evaluation of Initial Methodologies for Assessing Socioeconomic and Secondary Environmental Impacts of Western Energy Resource Development*, Working Paper #2 for U.S., Council on Environmental Quality. Denver, Colo.: University of Denver, Research Institute, 1976.

TABLE 3-18: MANPOWER REQUIREMENT FOR ENERGY FACILITIES

Facility	Assumed Facility Size	Manpower Requirements[a] (Man Years)	
		For Assumed Facility	For Production of 10^{15} Btu/year[b]
Coal			
Surface Mine	12.7 MMtpy	760	2,900
Underground Mine	12.7 MMtpy	3,550	12,900
Gasification	250 MMcfd	5,270	58,500
Liquefaction	100,000 bbl/day	8,280	36,300
Power Plant	3,000 MWe	2,980	
Btu (e)			36,200
Btu (th)			11,600
Oil Shale			
Surface Mine	140,000 tpd	1,370	3,600
Underground Mine	140,000 tpd	1,890	5,000
Retort and Processing	100,000 bbl/day	3,330	14,500
Crude Oil			
Production	100,000 bbl/day	5,970	26,100
Natural Gas			
Production	250 MMcfd	2,490	27,700
Uranium[c]			
Open Pit Mine	1,200 tpd	760	630
Underground Mine	1,200 tpd	1,280	3,100
Milling	1,200 tpd	200	500

bbl = barrel(s)
Btu = British thermal units
(th = thermal; e = electric)
MMcfd = million cubic feet per day

MMtpy = million tons per year
MWe = megawatts-electric
tpd = tons per day

Source: Carasso, M., *et al.* *The Energy Supply Planning Model*. San Francisco, Calif.: Bechtel Corporation, 1975.

[a] Includes both peak construction and operation employment requirements (see Table 3-5).

[b] 10^{15} Btu's per year in the product.

[c] Assumes ore contains approximately 0.2 percent uranium oxide.

B. Scheduling

The construction schedule for the energy facilities within a local area is an important technological factor which influences the extent of population impact on the area. When several facilities are constructed at the same time, the rate of population growth can be greater than that easily accommodated by a community.[1] For example, simultaneous scheduling of technologies that are labor intensive in their construction phase will cause the workers for two or more projects to be located in the same area at the same time. Currently, no means exist to coordinate the scheduling of several energy developments in an area, and such a goal might only be met by limiting the rate of development of western resources. Institutional inadequacies impede joint public and private sector planning. At the least, industry and local government often fail to communicate with each other in advance of development. Also, both are affected by federal policy and the associated uncertainties.

Conversely, if construction is prolonged, so is the period of population instability. It may be easier for communities to deal with temporary construction-related impacts if the period of instability is minimized.[2] If construction of successive projects involves large gaps of time with no construction, communities may become dependent on construction projects to reduce unemployment and add to local economic stability.[3] On the other hand, service shortages may occur each time construction occurs and unemployment when it does not.

C. Capital Intensity

A community benefits economically from energy development primarily through: increases in its tax base and revenues beyond the expenditures needed to meet expanded facilities and services requirements; and increases in personal incomes. Given the tax structure in most communities, an expanded property tax base and increased revenues are the most important sources of benefit;

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[1] Walton, Barry L. "Population Growth Constrained Synthetic Liquid Fuel Implementation Scenarios," Chapter 22 in Dickson, Edward M., et al. Impacts of Synthetic Liquid Fuel Development: Automotive Market, Vol. III. Menlo Park, Calif.: Stanford Research Institute, 1976.

[2] Planning for stability would require adequate information from all energy developers in the area as well as an adequate professional planning capability.

[3] Page, Arizona is an example; see Josephy, Alvin M. "Kaiparowits: The Ultimate Obscenity." Audubon, Vol.78 (March 1976), pp. 64-90.

the extent of the community's benefit from both depends on the capital intensity of energy facilities. Large conversion facilities, in particular, are large contributors to local revenues and can produce substantial excess revenues in the long term.[1]

In the short term, however, even capital-intensive facilities cause problems because property taxes generally are not available during construction when the demands on local governments are often greatest. Further, the jurisdictional division between municipalities and counties commonly results in municipalities experiencing most of the population impact and service demands while the counties and school districts receive the taxation benefits. This is discussed further in Section 3.4.3.

Local merchants and local residents employed by energy developers tend to gain most economically during the construction phase. However, the majority of construction workers usually come from outside. This, of course, reduces the benefits that residents often anticipate before construction begins. During operation, a relatively larger number of workers tend to be local residents, and new opportunities open up in local service industries.

3.4.3 Variations in Existing Conditions

The conditions that exist at an energy development site play a large part in determining the actual type and degree of social, economic, and political impacts. For example, impacts will vary depending upon such factors as community size and location, capabilities of existing institutions, historical outmigration, characteristics of the local labor force, local financial conditions, and the culture and lifestyle of an area.

A. Community Size and Location

The most important existing condition that influences the extent of population impact is the size of a community before energy development begins. Larger cities have more diversity and capacity for growth in both the public and private sectors. Our research suggests that communities of less than 2,000 population will almost always have inadequate services and planning capabilities.[2] Communities of up to 5,000 also may fall into this category. Conversely, cities of 10,000 or more (especially those greater than [illegible],000) usually have a developed community service system and planning professionals. Thus, in most larger communities, lead-time problems are reduced because they generally have plans for expansion, although acquiring funds for expansion may be a problem regardless of city size.

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[1] For details on the local scenarios, see Chapters 6 through 11.

[2] Planning and growth management capabilities are largely reflected in the existence of a full-time staff of professional planners, good knowledge of existing facilities in the town, and a plan of future developments in anticipation of growth.

In addition to size, the number of communities in the vicinity of an energy development will affect the relative impacts on each town. An isolated town that is the only possible place for workers and their families to live will receive much greater impacts than any one town in an area where the new population is more widely distributed.[1] Construction of a new town is a partial solution to the inability of any single community to absorb new population. This solution has been suggested in the Farmington, New Mexico and Kaiparowits, Utah areas (see Chapters 6 and 7). A similar solution is for an energy developer to provide housing and community services by expanding an existing village or town, as has occurred at Colstrip, Montana and Wright, Wyoming (formerly just a crossroads south of Gillette). However, developers do not always provide community services, leaving the cost of streets, water, sewer, and other services to very small, often unincorporated towns. State and county laws and regulations are not adequate in some cases to control growth in these settlements. Large cities, of 25,000 population or more, can absorb considerable population growth much more easily, simply because the growth represents a smaller proportion of their initial size.

Although the private sector often is slow in responding to increased demands for goods and services in rapid-growth situations, the reaction of local governments has tended to be even slower, especially in smaller towns.[2] Availability of funds is a major cause of this lag for all communities, but the time span is usually greater in small communities because of their lack of planning capabilities. Moreover, outside entities, rather than local businesses, are more likely to meet service needs in smaller communities, with the result that much of the economic benefit can filter out of the local area.

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[1] Gillette's isolation in northeastern Wyoming causes greater impacts there than occur in the Rifle-Rangely-Meeker-Grand Valley area of western Colorado, where several towns share the impacts. See Chapters 8 (Rifle) and 9 (Gillette).

[2] Breese, Gerald, et al. *The Impact of Large Installations on Nearby Areas: Accelerated Urban Growth*. Beverly Hills, Calif.: Sage, 1965, p. 589.

B. Capabilities of Existing Institutions

As the site-specific analyses in Chapters 6-11 indicate, growth leads to demands for housing and essential public facilities and public services, for professional services, and ultimately for social and cultural opportunities. Many western rural communities are not accustomed to providing such a full range of services and, in any case, are severely strained by the rate at which these demands escalate. Moreover, the manageability of these problems is often reduced by inadequate tax bases and planning capabilities. (See the discussion of community facilities and services in Chapter 14.)

Besides governmental service problems related to growth, most small communities affected by energy development will more than double in size, resulting in newcomers outnumbering natives (including former residents who return because of the employment opportunities energy developments offer). Not only will community leadership probably shift from the small businessmen and ranchers who presently lead these communities, but the dominant attitudes and values of the townspeople will probably change. Thus, the new majorities and leaders may force communities to make changes and undertake programs that they presently oppose. For example, many of these communities have an antipathy to planning and are reluctant to seek or accept assistance from other levels of government.[1] Yet, regardless of leadership or values, most of these communities must develop a planning capability and accept intervention and assistance from state and federal governments. In fact, these communities may even play a leading role in bringing pressure to bear on state and federal governments to provide assistance.

Increased strain in intergovernmental relations is another impact of rapid population growth. The sources of strain can be found in almost every problem area that has been discussed in this chapter, but particularly in the problems of: the benefits of public revenue increases accruing to jurisdictions other than the ones which must provide expanded municipal services; the pressure on the states and the federal government to provide assistance to impacted areas; and uncoordinated regulatory and policy roles assumed by various levels of government. (See the discussion in Chapter 13.)

C. Historical Out-Migration

Some areas, particularly in the Northern Great Plains, have seen their populations decline gradually for several decades.[1] In some ways, historical out-migration puts those areas in a better position to accommodate rapid energy development. First, excess capacity in adequately maintained community facilities, such as schools and water supply, could allow time before new facilities must be constructed. This is a luxury not available in most parts of the West; medium-size cities which have experienced recent growth generally have no excess capacity.[2]

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[1] See Christiansen, Bill, and Theodore H. Clack, Jr. "A Western Perspective on Energy: A Plea for Rational Energy Planning." Science, Vol. 194 (November 5, 1976), pp. 578-584.

Another advantage of recent out-migration is that many of the new energy related workers can be recruited from among those young people who previously moved away from these areas. These workers' families will view the return of their children as a benefit in itself, and, from a community point of view, less social readjustment will be necessary than with a workforce completely unfamiliar to the area.

D. Local Labor Force

Another existing condition that influences the extent of population impact concerns the size and composition of the local labor force. If local unemployed and underemployed persons are afforded the opportunity of training programs, the number of nonlocal workers required might be significantly lowered. This is more easily accomplished for operation than for construction trades, which often require years of specialized experience. Of all construction occupations, those most likely to be filled by local residents are laborers, cement finishers, and carpenters, but even those occupations have involved 40- to 50-percent nonlocal workers. The proportion is up to 80 percent for some skills.[3]

Even where lease clauses require that Indians be given preference in hiring, the lack of training among Indians is a barrier. However, many Navajo workers have acquired training, especially in coal mining operations. Many have also joined labor unions, at least in part because of the higher earnings associated with union jobs.[1]

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[1] For example, North Dakota has faced net declines in three of the last four decades.

[2] Mountain Plains Federal Regional Council. *Compilation of Raw Data on Energy Impacted Communities Including Characteristics, Conditions, Resources and Structures.* Denver, Colo.: Mountain Plains Federal Regional Council, 1976.

[3] Mountain West Research. *Construction Worker Profile,* Final Report. Washington, D.C.: Old West Regional Commission, 1976.

Unless lease terms or training programs benefit local residents, the largest category of new employment for local residents tends to be in relatively low-paying service jobs, perhaps in new businesses established by local entrepreneurs.[2] Professional and other, more specialized service jobs (such as in medicine and education) induced by population growth also commonly go to outsiders. Larger communities will experience more job switching to new employment opportunities, but even in these towns specialized skills are unlikely to be available in great numbers.

E. Local Financial Conditions

Two major site-specific variables are the legal and financial capacities of local governments to respond in a timely manner. Some state governments have passed legislation enabling communities to act decisively on their own and have established programs to provide funding assistance specifically aimed at impacted communities.

The adequacy of new revenue for impacted communities will depend primarily on timing and distribution; that is, funds for the expansion of existing community facilities and services will not always be available at the proper times or in the most appropriate jurisdictions. Four of the states in the study area (Montana, North Dakota, Utah, and Wyoming) have taken special actions to deal with the initial capital requirements of cities and counties. Their programs are described in the impact analyses reported in Chapters 6 through 12. Briefly, these programs provide impacted communities "front-end" money with which to meet facilities and service requirements. Utah permits the pre-payment of taxes for state-related public improvements; Montana, North Dakota, and Wyoming have a statutory formula for earmarking a portion of revenues from mineral leasing and severance taxes for payment directly to the impacted communities; and Wyoming has established a community development authority to issue bonds backed by future tax revenues.

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[1] The United Mine Workers operate the Black Mesa Mines, and the Operating Engineers man the Utah International Mine at Four Corners. Locals of both unions have approximately 70-percent Navajo membership. Robbins, Lynn A. *Navajo Participation in Labor Unions*. Lake Powell Research Project Bulletin No. 15 Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1975.

[2] Gray, Irwin. "Employment Effect of a New Industry in a Rural Area." *Monthly Labor Review*, Vol. 92 (June 1969), pp. 26-30; Summers, Gene F., *et al*. *Industrial Invasion of Nonmetropolitan America*. New York, N.Y.: Praeger, 1976.

However, state programs resolve only part of the timing problem associated with getting funds to local governments and do even less to resolve completely the larger distribution problem. For example, county governments, the principal recipient of ad valorem property taxes, are often major beneficiaries of new revenues produced by energy development, but as noted earlier, cities and towns normally must provide most of the services and facilities. In such states as Utah, Wyoming, and Colorado, special districts for water, sewers, schools, fire protection, and other purposes can bridge the city/county jurisdictional boundary and insure that new revenues are used at the impacted locations.

Based on the results of the regional impact analysis reported in Section 12.4.4, energy-related revenues at most state and local levels will probably exceed the new revenues required to serve the expanded populations. However, the types of legislation discussed here (and conscientious administration of the programs by the designated state boards) will be necessary to insure that the revenues are used when and where they are needed. The present programs in some western states have the opposite effect and, in fact, cause a lag between impacts being experienced on the local level and revenues being required from the state.

F. Quality of Life, Lifestyle, and Culture

"Quality of life" is largely a subjective attribute comprised of a variety of factors. Usually, though, the availability of medical care, professional services in general, and adequate housing play an important role in residents' opinions on the quality of their lives. When public and private services are unavailable, the local quality of life is generally considered to be low.[1]

The capability to plan adequately for local population impacts will largely determine the quality-of-life impacts in the West. Service infrastructure, such as utilities and streets, are common concerns for local residents. In the private sector, housing shortages handled by mobile homes are not very satisfactory either to those living in them or others in the community. For a variety of reasons, doctors tend not to locate in small, isolated towns, making medical care a particular area of concern for energy impacted communities.[2] Industry response in these service areas is variable, and cooperation with local governments will doubtless be needed to maintain quality of life.

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[1] Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976.

[2] Coleman, Sinclair. Physician Distribution and Rural Access to Medical Services, R-1887-HEW. Santa Monica, Calif.: Rand Corporation, 1976.

Lifestyle and cultural differences influence the way in which individuals perceive local attributes. Long-time residents in some isolated areas tend neither to expect nor to need the same set of services as newcomers, although in some areas newcomers and long-time residents have held similar opinions about local conditions.[1] Generally, opinions are affected by the contrasts in the lifestyles of ranchers and townspeople, energy development workers and farmers, Mormons and non-Mormons, and, perhaps most noticeably, Indians and non-Indians. Although the other differences are to some extent cultural, the clear-cut contrast between Indian and non-Indian values and societies are the most noticeable examples of cultural differences.[2]

Locations of archaeological or historical significance can also create cultural problems if they are disturbed by energy developments. A development might be delayed by the archaeological excavation of an ancient town, or the development might need to be relocated to avoid an ancient burial ground. Thus, the location and value of such sites within the development areas should be determined in advance of the actual energy developments.

3.4.4 Summary of the Interactions between Technological and Locational Factors

When a technology-related, impact-causing factor interacts with certain site-related conditions, social, economic, and political impacts can be magnified. Potentially critical problems are listed in Table 3-19 together with the combination of technology- and site-related factors that cause them.

Coal synthetic fuels technologies (and to a lesser extent oil shale retorting and electric power generation) are labor intensive; in addition, their peak construction labor requirements exceeds their operation labor requirements in varying degrees. High labor intensity and high peak construction to operation labor ratios, in combination with small, isolated communities where institutional planning capacity and financial

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[1] See: Mountain West Research. Construction Worker Profile: Community Reports. Washington, D.C.: Old West Regional Commission, 1976; Mountain West Research. Construction Worker Profile, Final Report. Washington, D.C.: Old West Regional Commission, 1976, p. 126.

[2] See: U.S., Department of the Interior, Bureau of Indian Affairs, Planning Support Group. Draft Environmental Impact Statement: Navajo-Exxon Uranium Development. Billings, Mont.: Bureau of Indian Affairs, 1976.

TABLE 3-19: SUMMARY OF SOCIAL, ECONOMIC, AND POLITICAL PROBLEMS

Social, Economic, and Political Problems	Combinations of Factors That Cause the Problem	
	Technological	Locational
Severely inadequate housing and services, difficulties for planning	High labor intensity for any one facility	Small isolated communities: inadequate institutional capacity and financial capability
Inadequate housing and services	Scheduling multiple labor intensive facilities simultaneously	Larger communities, inadequate institutional capacity and financial capability
Benefits accrue to newcomers rather than oldtimers	High labor intensity for any one facility	Size and character of the local labor force
Financial discontinuities, strained intergovernmental relations	Labor intensity and capital intensity	Jurisdictional arrangements for income distribution, state impact mitigation programs

capabilities are inadequate, cause social impacts to be magnified into critical problems (e.g., inadequate housing, schools, roads, health care, etc.).

A substantial number of the impacts on these communities can be alleviated (or even eliminated) if the development choice is to "strip and ship" the coal rather than to convert it to some other energy form at the mine-mouth. In fact, local communities might escape most of the stresses and strains associated with energy resource development if more of the raw sources were exported from, rather than being converted within, the region. However, although population impacts and certain physical environmental impacts would be reduced, some fiscal disadvantages are associated with the export option. The most obvious disadvantage is that taxes based on the assessed valuation of large-scale conversion facilities and activities would accrue elsewhere; that is, the tax base of the locality would not expand as much as it otherwise would.[1] If that tax gap is to be filled, the typical fiscal alternative would be to develop an extraction tax that falls either directly or indirectly on mining activity. This would tend to raise the price of energy delivered to the conversion facility (e.g., a power plant near Chicago), perhaps putting the exporting state at a competitive disadvantage with states that have lower severance taxes. The extreme effect could be to drive mining companies to other states.

A final consideration is that if mining the resource to be exported is relatively labor intensive (as underground coal mining is), the negative economic impacts on state and local governments may be magnified. In such a case, the increased population would have to be served, but, as stated above, much of the tax base would have been exported together with the coal.

Scheduling multiple labor intensive technologies so that the rate of increase in demand for services escalates rapidly causes the same impact problems as those described above. However, the scheduling factor causes the problems to become critical for larger communities as well as small, isolated ones. Coordinating the scheduling of several energy developments, especially several conversion facilities, in an area may only be possible by limiting the rate of development of western resources.

The extent to which the local labor force can be tapped by the energy facility will largely determine the distribution of income benefits between oldtimers and newcomers. Because of the specific skill mix and overall labor requirements, mining can generally draw on the local labor force for a significant percentage of labor requirements. On the other hand, the skills required for conversion facilities (especially during construction) are quite specialized and overall labor requirements are high. The percentage of newcomers required by them will be much greater than those for mining. Training programs aimed at the local labor force can alleviate the problem to some degree.

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[1] These disadvantages would be less pronounced in those states which have supplanted local property taxes with state severance taxes (e.g., North Dakota).

The combination of the capital intensity and labor intensity of a technology determines the relationship between financial benefits from development (in the form of tax revenues and personal income increases) and financial costs (in the form of housing, schools, and other services). While the financial benefits which accrue from conversion facilities generally exceed their finanical cost, the jurisdiction (e.g., municipality) which must bear the cost does not always receive the benefit. Jurisdictional arrangements for distributing the financial benefits vary by site. In the states that do not have legislation which enables communities to act on their own or do not have programs to provide funding assistance aimed at impacted communities, this income distribution problem will be critical and lead to strained intergovernmental relations. Colorado and New Mexico do not have such arrangements. Arrangements in other states vary from legislation which permits the prepayment of taxes (Utah) to payment of a portion of lease and severance taxes to impacted communities (Montana, North Dakota, and Wyoming).

The labor requirement of each technology emerges from this analysis as the major determinant of social, economic, and political impacts. Coal conversion technologies in particular cause a large population influx, which impact small communities most severely. Construction of several facilities at once only exacerbates the population-related impacts on local areas. On the other hand, the coal conversion facilities also contribute most substantially to the local tax base.

3.4.5 Data Limitations

This section has relied on available information concerning manpower and capital requirements of energy technologies. All involve uncertainty; this uncertainty is highest for future, relatively untested technologies. Other plausible estimates of manpower needs could result in different impacts. In addition to employment data shortcomings, the economic base/population impact methodology remains very subjective in nature. Basic/nonbasic employment ratios used in this report were selected after extensive review of other research, but the review only reinforced the awareness that the range of multiplier estimates is quite large and that selection within the range is subjective. Further, employment multipliers and population multipliers are largely based on past data, which may not be adequate for future extrapolations.

Estimates of expenditure needs and anticipated revenues also are based on incomplete information. When combined with the population estimates discussed above, the potential for uncertainty in the economic projections is even greater.

In impact categories where numerical data are scarce (such as social, cultural, and political impacts), the lack of information prevented a comprehensive assessment in this study. Quality-of-life data, especially those beyond standard social indicators, are extremely scarce for local areas in the West. Social antagonisms and cultural conflicts are some of the items that have resisted attempts at more quantitative or precise discussion. Some limited recent information (largely anecdotal) from the West has been the basis for some treatments of future problems in this report. This may be a questionable basis for the long-range time span of concern, but prediction of social or interpersonal behavior remains among the least certain areas of research. Future research attention could profitably focus on social groups and "people" impacts, rather than on methodologies and quantitative data.

3.5 ECOLOGICAL

HIGHLIGHTS

• CRITICAL FACTORS

- *Four technological factors can significantly affect the ecological impacts of energy development: land requirements, water requirements, labor intensity and air emissions.*
- *Four locational factors can also significantly affect these impacts: climate, topography, soils, and plant and animal communities.*

• LAND REQUIREMENTS

- *Direct land use by surface mining can be 10 times greater than for underground mines and coal conversion facilities.*
- *Direct land use for oil shale development is two to six times greater than for surface mining.*
- *Surface coal mines in New Mexico and North Dakota use six times more land than do surface mines in Wyoming to produce the same amount of energy.*

  - *Land use to meet the needs of energy-related population growth generally produces more significant ecological impacts than does land used directly by the energy facilities.*
  - *Land use by any single development generally disturbs only a small percentage of a habitat type; however, even a small disturbance can be significant if the habitat is of a rare type, as aquatic habitat is in the study area.*
  - *By the year 2000, large-scale development could disturb a significant percentage of some types of habitat and fragment habitat to the point of eliminating some mammal and bird populations.*

- **WATER REQUIREMENTS**
  - *Withdrawals of local surface water by any single conversion facility generally will not have a significant impact on aquatic habitat; western Colorado is an exception.*
  - *Withdrawals of local surface waters for multiple facilities at the same location could eliminate some sport fish from streams and alter the plant communities supporting other fish.*

- **LABOR INTENSITY**
  - *The more labor intensive a technology, the more likely ecological impacts are to be significant as a result of land use, habitat fragmentation, water withdrawals, and recreation. Population related impacts are usually larger than disturbances from facilities.*

- **RECLAMATION**
  - *The reclamation potential for reestablishing vegetation is greater in the Northern Great Plains than for any other part of the eight-state study area.*

- **PUBLIC LANDS**
  - *Public lands, particularly those in a natural state, are likely to experience the greatest changes, primarily as a consequence of population increases and easier access.*

- **EMISSIONS AND EFFLUENTS**
  - *In rough terrain, sulfur dioxide levels produced by conversion facilities can result in acute local damage to vegetation.*
  - *Although the consequences are not adequately understood, trace elements in air emissions and water effluents can enter the ecosystem food web; for some substances such as mercury, concentrations in the tissue of carnivores already exceed government standards.*

3.5.1 Introduction

Both the severity and form of ecological impacts depend on the kind of technology deployed and the type of ecosystem in which it is deployed. For example, technologies differ in their land, water, and labor requirements, and sites differ in their climate, topography, soils, and plant and animal communities. The ecological impacts that result from energy development are difficult to describe in quantitative terms; however, it is possible to identify technological and site specific factors that cause impacts to vary and to describe those variations qualitatively.

3.5.2 Variations by Technologies

Six factors that vary among technologies can have major effects on the severity of impacts on ecosystems: land use, labor intensiveness during both the construction and operation phases; water requirements of the technology and other induced in-stream flow changes; effluents; air emissions; and type of transportation system associated with the energy product.

A. Land Use

First-order, direct ecological impacts are caused by land disturbances at mine and plant sites. These disturbances result in the complete removal of vegetation and animals dependent on this vegetation for some time period. Variations in land use by technology are given in Table 3-20 for the size facilities deployed in our scenarios and on an equivalent energy basis. Note that conversion facility land requirements do not differ significantly. Land use for an underground coal mine is similar to that for conversion facilities, but land use for surface coal mines can be 10 times greater depending on the seam thickness and heating value of the coal. Oil shale mines require significantly more land than any other technology, principally because of the land required for spent shale disposal.

TABLE 3-23: LAND USE BY TECHNOLOGY

Facility	Typical Size (acres/30-year life of facility)	Equivalent Energy (acres/10^{12} Btu in product)
Conversion Facilities		
Power Plant (3000 MWe)	2,400	0.9
		0.3
Lurgi Gas (250 MMcfd)	805	0.3
Synthane Gas (250 MMcfd)	805	0.3
Synthoil Oil (100,000 bbl/day)	2,060	0.3
Oil Shale Retort (100,000 bbl/day)	1,280	0.2
Mines		
Underground Oil Shale[a] (50 MMtpy)	35,100	6
Underground Coal[b] (12 MMtpy)	1,700	0.1
Surface Coal[c] (12 MMtpy)	4,200-16,000	0.5-3.2

bbl = barrels
Btu = British thermal units
MMcfd = million cubic feet per day

MMtpy = million tons per year
MWe = megawatts-electric

[a] Includes the land requirements for spent shale disposal.

[b] This is the land that is permanently occupied.

[c] The range of values is the range found in the six site-specific cases analyzed.

By eliminating vegetation, direct land use reduces the overall carrying capacity of an area, fragments habitat types, and may increase erosion. When carrying capacities are lowered, animal populations, such as deer and elk, may also be reduced. Fragmentation may further reduce animal populations that range or migrate over large areas. Increased erosion will speed removal of nutrients from affected areas within ecosystems. Thus, where nutrients already limit vegetation growth, increased erosion will further reduce both growth and carrying capacity for animals.

Generally, the amount of land disturbed directly by any one mine-plant combination is small in comparison to the land area of entire counties or in comparison to the total amount of habitat in a region. Thus, the impacts resulting from direct land use generally occur only locally; they have regional importance only when the particular ecosystem type disturbed is rare or supports endangered species. For example, riparian ecosystem types are rare in the West as compared to desert shrub communities. Eliminating 5 percent of the riparian habitat in a location has vastly greater impacts than eliminating 5 percent of a desert shrub community. Similarly, eliminating black-footed ferret habitat (an endangered species) has different implications than eliminating mule deer habitat.

At the aggregate level, as many facilities are sited in one location, direct land use can eliminate or affect a large percentage of habitat types and result in significant reductions in carrying capacity. Entire populations of animal species such as deer and elk could be eliminated in these locations, and their overall range in the West will be reduced.

Because surface mines disturb much greater amounts of land than conversion facilities, reclamation of surface mined lands has the potential of mitigating these ecological impacts; that is, reclamation as a means to mitigate impacts becomes very significant as energy development expands at any one location. For example, development of one oil shale retorting facility in the vicinity of Rifle, Colorado disturbs less than 1 percent of the land area in Garfield and southern Rio Blanco Counties. Construction of 40 such facilities (as in Stanford Research Institute's Nominal Demand Case) would disturb about 35 percent. Ecological impacts tend to increase exponentially with such expansion; for example, carrying capacity for deer would decrease exponentially. In this example, carrying capacity would decrease more than 35 percent and could cause some animal populations to leave large areas.

B. Labor Intensiveness

Variations in the labor intensities of technologies may be a more important technology-related variable in terms of ecological impacts than is land use by the facilities or mines. If reclamation attempts are successful and widespread, impacts caused by people will likely be more severe than those caused by facility-related land use. In addition to the direct contribution of increased population to air and water pollution, land requirements increase to meet their housing, transportation, and service needs, and recreational activities increase.[1] Technologies differ in labor intensiveness during both the construction and operation phases.[2] Overall, conversion technologies are more labor intensive than mining, and surface mining is the least labor intensive energy technology deployed in our scenarios. Underground mining tends to have low construction but high operating labor requirements; the reverse is the case for electric power plants.

The type of ecological impacts that result from population increases are similar to those caused by land use for facility siting. More housing, roads, and service activity fragment habitat into small parcels that are less usable by either resident or migratory species. Easier access to recreational areas often results in increased hunting, some of which is illegal. Increased recreational use can also result in increased erosion, damage to vegetation, degradation of aquatic habitat, and disturbances to terrestrial wildlife. Habitats which are most at risk are high alpine ecosystems (particularly lakes), high and middle-elevation stream systems, and riparian habitats in desert environments. Where public land is accessible to urban populations associated with energy development, back-country recreation in the form of camping, hunting, fishing, and off-road vehicle use will be extensive. Extensive recreational activities such as these can cause major ecological changes.

C. Water Requirements and Aquifer Interruption

The most pervasive ecological changes resulting from energy resource development will occur in those streams and rivers that experience severe reductions in flow resulting from consumptive water use, groundwater depletion, runoff interception, and stream impoundment. The water requirements of different technologies and opportunities to minimize water use can significantly affect ecological impacts.

As indicated in Section 3.3, among the conversion technologies deployed in our scenarios, electric power generation is the greatest consumer of water, and cooling represents the single larger water use. Lurgi gasification requires less water than any other conversion facility; surface mining water requirements (including irrigation) are an order of magnitude less than those for conversion facilities. At this stage in our analyses, it appears that finding ways to minimize cooling water requirements can contribute to minimizing the threat to aquatic ecosystems.

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[1] Personal communication with the Grand Junction Field Office of the Colorado Division of Wildlife, 1976.

[2] Data on the labor intensiveness of the technologies deployed in our scenario is presented in Section 3.4.

The water savings that could result from the use of wet/dry rather than wet cooling were discussed in Section 3.3.[1] Total consumptive water use by these technologies can be reduced up to about 75 percent with the use of wet/dry cooling. Percentage reductions are potentially greatest for an electric power plant and least for an oil shale facility. Water savings can total up to 17,940 acre-feet per year for a 3,000-megawatt-electric power generating plant, 4,230 acre-feet per year for a 250-million cubic feet per year coal gasification facility, 6,550 acre-feet per year for a Synthoil liquefaction facility, and 2,170 acre-feet per year for a TOSCO II oil shale facility. In several of these cases, the savings for an individual facility are large enough to affect aquatic ecosystem impacts at some sites in our eight-state study area. And when the potential for savings is aggregated for facilities in the same watershed, the consequences for aquatic ecosystem impacts could be significant.

Our analysis of six sites suggests that impacts caused by flow reductions vary seasonally. Normal flows in spring will be sufficient for fish migration and spawning; lower flows during summer will reduce habitat and lower water quality, thereby interfering with the growth and survival of some fishes; and low flows in winter can cause ice-scouring, thereby reducing the population of aquatic invertebrates that support fish in spring and summer. Flow reductions also narrow the margin of marshlike habitat which parallels many streams. This riparian habitat supports large and diverse communities of waterfowl and shorebirds. Since riparian habitat is particularly scarce in the eight-state study area, any reduction constitutes a large percentage lost in its availability.

Both coal and oil shale mines require dewatering as mining progresses. Dewatering represents withdrawal of groundwater and affects aquifers as well as the surface streams fed by those aquifers. The marsh habitat along stream margins often represents the interface of groundwater with surface water. To the extent that aquifers are dewatered, that margin will be narrowed or eliminated.

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[1] Once-through cooling was not considered. If used, it could produce an ecological problem because of its thermal discharge. Dry cooling was not considered either although it would have no impact on aquatic ecosystems. However, with dry cooling, plant efficiency would be lowered.

D. Wastewater Effluents

Wastewater for conversion facilities is generally controlled by impounding it in on-site evaporation holding ponds. Construction of impoundments for power plant and synthetic fuel effluents are similar; impounding runoff from spent shale has also been proposed.

Both the quantity of effluent and content of the effluent varies by technology. Variations in quantity are discussed in Section 3.3, which indicates that synthetic fuels facilities produce less wet-solids than do electric power plants equipped with scrubbers and that oil shale processing produces more than coal gasification.

Variations in the content of effluent streams have not been analyzed in the first year of this study beyond identifying whether the wastes are organic/inorganic and soluble/insoluble. In general, impounded effluents from a power plant consist mainly of flue gas desulfurization sludge and ash, while effluents from synthetic fuel facilities consist mainly of ash. Effluents from synthetic fuels facilities contain heavy metals such as nickel, zinc, and lead as well as potentially cancer-producing aromatic hydrocarbons. If the berms around impoundments fail or erode, the wastes could physically obliterate some stream communities, rendering them unstable and reducing productivity for several years.[1] Berm failure is improbable over the short-term but uncertain over the long-term. Additionally, some metals may migrate through the liners in the impoundments even if they are properly designed and maintained. If the liner should leak, groundwater and surface water could be contaminated. Although they migrate more slowly than most impounded chemicals, heavy metals can become a problem. Heavy metal contamination constitutes an addition of minerals to the mineral cycles of the stream ecosystems where they are cycled in and through the food webs. In some cases, the waste elements are foreign to the system; in others, their addition will result in abnormally large amounts or concentrations. Both aquatic plants and animals have low tolerance to heavy metals. Also, where water is used for drinking and/or fish taken from the streams are eaten by people, contamination carries with it potential health hazards. The extent to which contamination and food web uptake is likely to occur is largely a matter of speculation at this time.

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[1] U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado. Washington, D.C.: Bureau of Land Management, 1975.

E. Air Emissions

As described in Section 3.2, quantities of air emissions vary by technology. Of the criteria pollutants, sulfur dioxide and oxides of nitrogen emissions can potentially cause ecological impacts. Emission of both are greatest from electric power plants. Our analysis also indicates that acid rainfall (either in the form of sulfuric or nitric acid) is unlikely to become a region-wide problem even given the levels of emissions from power plants, primarily because of the low humidity and limited rainfall in most of the study area. Similarly, although dry deposition of sulfates and nitrates will occur, soil acidification increases will not be sufficient to affect vegetation or streams.

Ground-level sulfur dioxide concentrations within the ranges expected to develop under worst-case conditions are known to cause both chronic and acute damage to sensitive native and crop plants.[1] However, the duration and frequency of these episodes in most western locations are not expected to result in damage to plant communities. Exceptions occur in the case of emissions from electric power plants in areas of rugged terrain (as in southern Utah) and in the case of sulfur emissions from oil shale facilities in western Colorado where plume impaction and air stagnation can subject vegetation to acute damage in areas of from 1-3 square miles. Chronic damage over larger areas is possible in the oil shale area.

Mercury is contained in some stack gases from power plants and coal synthetic fuels facilities. While the amount of mercury released probably varies considerably among technologies, data are not sufficient to make those comparisons. In some southwestern lakes, notably Lake Powell, mercury concentrations in some predatory fish already exceed Food and Drug Administration standards for safe human consumption.[2] Additional mercury would exacerbate this problem. Projections based on Lake Powell studies indicate that energy development might cause mercury increases between 10-[illegible]0 percent, depending on the number of facilities and the composition of the coals being used.[1]

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[1] See, for example: Hertzendorf, M.D. Air Pollution Control Guidebook to U.S. Regulations. Westport, Conn.: Technomic, 1973, pp. 154-155; U.S. Department of Health, Education and Welfare, Public Health Service. "Effects of Sulfur Dioxides in the Atmosphere on Vegetation," in Air Quality Criteria for Sulfur Oxides. Washington, D.C.: Public Health Service, 1969, pp. 61-69; and Benedict, H.M., C.J. Miller, and R.E. Olson. Economic Impact of Air Pollutants on Plants in the United States. Menlo Park, Calif.: Stanford Research Institute, 1971, pp. 40-46.

[2] Standiford, D.R., L.D. Potter, and D.E. Kidd. Mercury in the Lake Powell Ecosystem. Lake Powell Research Project Bulletin No. 1. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1973, p. 16.

F. Transportation Technologies

A transportation system for exportation is associated with each type of energy product. These systems include: unit trains; slurry, gas, and oil pipelines; and extra-high voltage (EHV) transmission lines. Each transportation system produces different types of ecological impacts. Our analysis suggests that unit train transport of coal is likely to be more destructive to biological resources than other transportation options.[2] Rail lines built for heavy unit train traffic pose a hazard to large animals (e.g., antelope) which move in herds over large areas during the year. Since some railroad right-of-way is likely to be fenced on both sides to protect livestock, the migration of some herds over their accustomed ranges will be restricted. For example, antelope do not jump over fences. Passes or a fence with a higher low wire may have to be constructed to allow them to pass. If animals get in the right-of-way between the fences, they are vulnerable to collisions with trains.[3]

Alternative methods for transporting resources should be less disruptive to wildlife. Pipelines result in negligible impacts. EHV transmission lines alter habitat types but that alteration may add beneficial ecological diversity to the region. At present, there is inadequate information about electric fields from EHV lines to assess impacts.

3.5.3 Variations by Existing Conditions

The severity of impacts summarized in the previous section is highly dependent on the ecological characteristics of the site at which the technologies are deployed. Important site-specific variables are grouped into three categories in this discussion. The first category includes the physical and biological characteristics of a site that, together, determine ecosystem stability and resiliency; these include climate, soils, and plant and animal communities. The second category includes variables associated with the character of present land use in a region;

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[1] Standiford, D.R., L.D. Potter, and D.E. Kidd. *Mercury in the Lake Powell Ecosystem*. Lake Powell Research Project Bulletin No. 1. Los Angeles, Calif.: University of California, Institute of Geophysics and Planetary Physics, 1973, p. 16.

[2] Slurry pipelines require 77 acre-feet of water per million tons of coal and can contribute to the water impacts discussed above.

[3] See Sections 3.7 and 9.5 for a more extensive description of levels of unit train traffic and the problem trains can pose for animals.

for example, the extent to which a region is pristine and the extent of public land ownership. The third category includes the affects of instream flow on impacts on aquatic ecosystems in the West.

With regard to the first category, the reclamation potential of a site and the response of an ecosystem to impacts such as exposure to chronic air pollutants depend on the ecosystem's stability and resiliency. Stability measures the ability of a system to remain unchanged under stressful conditions, whereas resiliency measures the ability of a system to recover following a stress induced change. The response of ecosystems in the West to impacts such as fragmentation, the addition of mineral elements, nutrient losses, and chronic exposure to air pollutants is largely a function of their stability. Conversely, reclamation potential is largely a function of resiliency.

With regard to the second category, the extent and kind of ecological impacts expected vary according to the overall character of the land being impacted. Impacts are different and are perceived differently in wilderness and agricultural areas and public and private lands.

The third category, stream flow, includes impacts on aquatic ecosystems (streams, lakes, and impoundments). Stream and river low flows vary greatly in the West and affect dilution of polluted runoff both in the stream and in downstream lakes and impoundments.

A. Ecosystem Stability and Resiliency

Factors that vary by site and are important in determining stability and resiliency are climate, soils, and plant and animal communities.

1. Climate

In the West, rainfall including its seasonal distribution is an important climatic variable. Average rainfall data for three areas within the eight-state study area are given in Table 3-21. Both total amounts and the seasonal distribution are included. The Southwest receives the least amount of rainfall overall. In the Rocky Mountain and Northern Great Plains, total rainfall is similar, but rainfall during the summer growing season in the Northern Great Plains is twice that of the Rocky Mountains. The amount of rainfall during the growing season is probably the single most important factor affecting reclamation potential. Reclamation will be more easily accomplished in the Northern Great Plains and most difficult (by some estimates, impossible) in the Southwest. Moreover, as indicated in Table 3-22, the reclamation problem is compounded since, for a mine supplying a conversion facility of the size deployed in our scenarios, the

TABLE 3-21: RAINFALL AVERAGES IN THE WEST

Region	Rainfall[a] (inches)		
	Winter	Summer	Annual
Northern Great Plains	<5	10-20	10-20
Rocky Mountains	5-10	5-10	10-20
Southwest	<5	<5	<10

< = less than

[a] Espenshade, Edward B., ed. Goode's World Atlas, 13th ed. Chicago, Ill.: Rand McNally, 1971; winter corresponds to November 1/April 30; summer corresponds to May 1/October 31.

amount of land requiring reclamation is largest in the Southwest (the Navajo/Farmington site on Table 3-22).

Using present reclamation techniques, areas averaging 10 or more inches of rainfall per year can generally support plant regrowth without supplemental irrigation. In most of the semi-arid Southwest, rainfall is regularly less than 10 inches and varies widely from year to year. Periodic dry periods lasting

TABLE 3-22: LAND USE FOR SURFACE COAL MINES BY SITE[a]

Site	Typical Size Mine[b] (acres over 30 years)	Energy Equivalent (acres per 10^{12} Btu)
Navajo/Farmington	27,820	1.2
Gillette	4,030	0.5
Colstrip	9,680	1.2
Beulah	24,210	3

Btu = British thermal units.

[a] Seam thickness and heating values assumed: Navajo/Farmington--10.3 feet, 8,600 Btu per pound; Gillette--64 feet, 8,000 Btu per pound; Colstrip--28 feet, 8,600 Btu per pound; Beulah--13 feet, 6,950 Btu per pound.

[b] In all cases, the mine size assumed supports a 3,000-megawatts-electric power plant.

up to several years further curtail successful revegetation.[1] The seasonal distribution of rainfall is perhaps the most critical variable; for example, a lack of precipitation shortly after planting can reduce seedling success, and a difference of only 1-2 inches over the entire growing season will have significant consequences, depending on when this rain falls. Because most reclamation studies have been initiated since 1970, there has been no opportunity to observe precisely how rainfall variations affect long-term reclamation success.[2]

2. Soils

Natural surface soils vary greatly within the eight-state study area; even a single mine site may contain several soil types differing in suitability for reclamation. In the Northern Great Plains, soils are generally well developed with adequate nutrient and organic matter. These soils have a high potential for use in mine-spoil revegetation. Topsoils may be 6-10 inches in depth. However, high sodium content is a problem in many Northern Great Plains soils, particularly parts of North Dakota and Montana. Runoff from such soils is typically high, and they tend to erode easily. North Dakota has enacted strict regulations on surface mining technologies that require several soil zones to be removed and saved separately. Each soil zone must then be replaced in sequence following mining.

Three major soil types are found in coal-producing regions of the Central Rocky Mountains: soils of dry sagebrush areas which are generally loamy but poor in organic matter; rocky or barren badlands soils which are less than 20 inches deep and subject to water erosion; and loamy, easily tilled soils which are rich in organic matter. These latter soils are usually found on western Colorado coal lands and are often farmed for dryland crops. All three types of soils will probably require irrigation for successful reclamation.

Soils in the arid areas where coal is formed in Arizona and New Mexico are generally poorly developed, have an unsatisfactory

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[1] National Academy of Sciences. Rehabilitation Potential of Western Coal Lands, a report to the Energy Policy Project of the Ford Foundation. Cambridge, Mass.: Ballinger, 1974; Packer, P.E. Rehabilitation Potentials and Limitations of Surface-Mined Land in the Northern Great Plains, General Technical Report INT-14. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1974.

[2] Farmer, E.E., et al. Revegetation Research on the Decker Coal Mine in Southeastern Montana, Research Paper INT-162. Ogden, Utah: U.S., Department of Agriculture, Forest Service, Inter-Mountain Forest and Range Experiment Station, 1974.

TABLE 3-23: PLANT COMMUNITIES AND THEIR PRODUCTIVITY

Region	Predominant Plant Communities	Primary Production[a] (grams per square meter per year)[b]
Northern Great Plains	Short grass prairie	600-900
	Mid grass prairie	600-1,100
	Bottomland forest	1,000-2,000
	Pine savanna	1,000-2,000
Rocky Mountains	Desert shrub	100-200
	Pinon-juniper woodland	500-1,000
	Mountain shrub	600-700
	Mountain meadows	700-1,100
	Coniferous forests	900-2,000
Southwest	Desert shrub	0-200
	Desert grassland	200-500
	Pinon-juniper woodland	500-1,000

[a] Ranges given are rounded estimates from Cooper, J.P., ed. Photosynthesis and Productivity in Different Environments, International Biological Programme 3. Cambridge, England: Cambridge University Press, 1975.

[b] In this context, primary production refers to the "net" production of organic matter (including root and shoot growth) by the plant community; that is, it measures the rate at which solar energy is converted to available organic matter.

moisture-holding capacity, and contain a high salt content. Moreover, these soils are sandy and eroded through overgrazing. Drifting and blowing soils in these areas can easily bury seedlings or reduce plant cover by abrasion.

3. Plant and Animal Communities

The dominant plant communities found in three areas of the eight western states are given in Table 3-23. For each area, these communities are listed in increasing order of structural complexity and productivity. In the Rocky Mountains and Southwest, the increase generally corresponds to increases in elevation with consequent higher rainfall. For example, in the Southwest, the desert shrub community is located at low elevations where rainfall is often less than five inches, whereas the pinon-juniper woodland is located at higher elevations where rainfall is often greater than ten inches.

The structural complexity of a plant community contributes to both its stability and resiliency. In general, the more complex a plant community is, the more stable but less resilient it is. A grassland is generally not as stable as a forest, and its ability to remain unchanged in the face of stresses is not as great as that of the forest. An example of this effect is where grasslands have been overgrazed and reverted to desert shrub communities. On the other hand, following a stress-induced change such as surface mining, a grassland will reestablish itself more readily than a forest. Similarly, it is easier to reestablish a desert shrub community than a grassland.

The productivity of a plant community is a measure of the rate at which the plants produce organic matter. Several factors may limit this rate. Soil characteristics and the seasonal distribution of rainfall probably dominate as limiting factors in the eight-state area. The Southwest, where low summer rainfall is small and soils are poorly developed, has the least capacity to produce organic matter in any one year (Table 3-23).

Irrigating reclaimed land represents an attempt to remove rainfall as a limiting factor, thus allowing higher primary production rates and faster revegetation. However, this approach is effective only to a degree. As one limiting factor is removed, another becomes limiting. Thus, an irrigated reclamation site may be limited by soil nutrients or by unusually high concentrations of salts. In the Southwest, rainfall is the dominant limiting factor. Consequently, irrigation will speed reclamation but only to a level where some other factor (such as soil salt concentrations) limit production. In the Northern Great Plains, rainfall may not be the dominant limiting factor; soil and temperature may also play important roles.

Productivity is also a measure of the community's ability to support animals. Carrying capacity for animals increases with productivity, and some animals (such as mule deer and elk) use several plant community types during a year. Based on the productivity values given in Table 3-23, high-elevation communities could support denser animal populations than those of the lower desert shrub communities, and the Great Plains can generally support denser animal populations than can the Southwest.

4. Summary

Climatic and soil variables and plant and animal types contribute to an ecosystem's response to change induced by energy development. These variables are significantly different in different parts of the eight-state area. Low rainfall (particularly during the growing season), poor soils, and low primary production rates will make reclamation difficult in the Southwest. Adequate rainfall during the growing season, better soils, and higher primary production rates will make the reestablishment of a plant community easier in the Northern Great Plains. However, even there, reestablishment of the original plant community (short- to mid-grass prairie) will take longer to reestablish than a simpler plant cover. The success of reclamation depends on the extent to which limiting factors can be identified and removed by, for example, irrigation, fertilization, seeding, and soil treatment.

Revegetation attempts are required by all eight states. Although the specific language in laws and regulations vary, most of the state programs are aimed at returning surface mined land to productive use. North Dakota requires segregation, saving, and replacement of topsoil and subsoil zones separately. However, in no state is a criterion of success in terms of vegetative survival delineated.

B. The Character of Present Land Use

The degree to which an area is still in a natural state before development occurs and the availability of public lands affect both the actual and perceived ecological impacts.

Changes in wilderness character occur rapidly when development is initiated but are slowed as development expands. For example, people generally travel only limited distances away from home for weekend recreation. As population increases with expanded development, recreational areas closer to the urban center are likely to become more heavily used while areas at greater distances are less likely to be affected. Similarly, the plant and animal populations of a community change rapidly when development is initiated and expands.

People also perceive impacts in wilderness areas differently; impacts of the same magnitude often are more obvious and seem greater. In the arid Southwest, particularly southern Utah, and in parts of western Colorado, both residents and visitors generally expect to encounter native plant communities, wildlife, and scenic vistas. On the other hand, the Northern Great Plains is heavily oriented toward agriculture and is already more developed than the arid Southwest. Thus, who reacts and how they react will depend on land uses before energy development begins. The agri-business community of the Northern Great Plains will react to impacts there, but that reaction will be different than that of environmental interest groups to impacts in wilderness areas.

The actual amount of change will likely be greatest when it occurs in wilderness areas, and the perception of that change will be different depending on the nature of pre-development conditions. The availability of public land in the vicinity of energy development also exerts an influence on ecological impacts. The Federal government owns 87 percent of the land in the area around Kaiparowits/Escalante, 70 percent around Rifle, 30 percent around Navajo/Farmington (an additional 60 percent of land around Farmington is Indian-owned), 12.6 percent around Gillette, and 5 percent around both Colstrip and Beulah. However, this pattern of public land ownership does not necessarily hold for the area around every site in any one area.

At present, public access to national forests is great, with few restrictions and limited enforcement on the abuse of public lands. Where public land is accessible to urban populations associated with energy development, back-country recreation in the form of camping, hunting, fishing, and off-road vehicle use will be extensive. Given few regulations and limited enforcement, this recreation can potentially cause major ecological damage. On the other hand, private land holders are likely to restrict recreational use of their land.

In addition to the fact that public lands (such as national forests, national parks, wildlife refugees, and designated wilderness areas) are accessible to the public, most high-quality wildlife habitat occurs on public land. To varying degrees, these habitats have remained unchanged or natural. Moreover, management priorities and enforcement authority vary greatly among the National Forest Service, Park Service, and Bureau of Sport Fisheries and Wildlife. We can expect impacts on public lands in close proximity to energy development to be significant. However, the extent of those impacts depends on management and enforcement practices.

C. Stream Flow

The greatest impacts on aquatic ecosystems will probably occur in the San Juan Basin, in the Utah-Colorado oil shale area, and, to a lesser extent, in the Yellowstone River Basin. Growth in large-scale agricultural irrigation combined with energy developments will consume water and add significant amounts of nutrient-, pesticide-, and silt-laden runoff to the San Juan. Impacts caused by the addition of pollutants from runoff will be exacerbated by flow reductions and consequent reductions in the dilution capacity of the river. The San Juan flows directly into Lake Powell, and those pollutants could affect biota in the San Juan arm of the lake.

In the oil shale country of western Colorado, water demands projected for the regional scenario would exceed typical minimum daily flow in the White River and other streams in the area. Consequently, these streams are not likely to be used as a water source unless impoundments are constructed to maintain flows. The Colorado, measured near Rifle, commonly experiences minimum daily flows that fall short of total demand for energy development projected by the year 2000. Four fish species officially classed as threatened by the U.S. Fish and Wildlife

Service inhabit the Colorado and Green Rivers and reproduce in the lower Green River.[1] Flow depletion will decrease populations of these species, which are already stressed by competition with introduced sport fishes.

The Yellowstone River Basin could experience withdrawals from the river itself or its tributaries amounting to about 22 percent of typical low flows, depending on the use of reservoirs to regulate discharge. From Billings, Montana to the Missouri confluence, the Yellowstone River is free-flowing; there is now strong public sentiment in favor of keeping it free of dams. Impoundments on tributaries to the Yellowstone are likely to interfere with the spawning movements of several fish indigenous to the Upper Missouri River Basin (e.g., the paddlefish, shovelnose sturgeon, and pallid sturgeon).

3.5.4 Summary of Technological and Locational Factors

Ecological impacts can be magnified when certain technological and locational factors interact. Often the resulting problems can be mitigated by choosing a different technology for the problem location, a different location for the problem technology, or an entirely different technology-locational combination.

This summary identifies technology-location combinations that cause significant ecological problems and suggests combinations that can mitigate the problems. Table 3-24 lists these ecological problems with the corresponding technological and locational factors that cause each problem.

Overall ecological degradation can be greatly increased when the land used affects habitat that is not abundant (e.g., riparian habitat or unique habitat used by endangered species or by wildlife during some part of their life cycle). Land used by surface coal mines producing the same amount of energy is highest at the Farmington site (because of thin seams) and Beulah site (because of low heating value coal) and lowest at the Gillette site (because of thick seams). Mitigation calls for a careful screening of potential mine sites.

Land use by multiple surface coal mines and oil shale facilities at a site can affect a large percentage of total habitat at that site; the resulting habitat fragmentation can eliminate wildlife from the site and locally eliminate endangered species. Mitigation calls for choosing sites for multiple mines that have high reclamation potential. Reclamation potential in the more arid areas in the West is uncertain. Successful reclamation depends on the ability and willingness to identify and overcome

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[1] These are the Colorado squawfish, humpback sucker, humpback chub, and the Colorado cutthroat trout.

TABLE 3-24: SUMMARY OF ECOLOGICAL PROBLEMS

Ecological Problems	Combinations of Factors that Cause the Problem	
	Technological	Locational
Local ecological degradation, species elimination or extinction	High labor intensity land use by any one surface coal mine or by an oil shale mining, and processing facility	Unique or rare habitat, and/or low heating value coal
Loss of ecosystems and associated wildlife through habitat fragmentation	High labor intensity and land use by multiple surface mines at any one site	Areas where reclamation potential is poor or where reclamation is not attempted
Reduction in the original habitat type and replacement in a new form, and declines in wildlife numbers and type	High labor intensity of synthetic fuels technologies and extensive development	Wilderness areas, proximity to public lands
Reduction or elimination of sport fish, aquatic habitat, and streamside ecosystems	Water intensiveness of conversion facilities	Limited and seasonal stream flow, limited extent of riparian habitat
Acute and chronic damage to vegetation	Air emissions by conversion facilities especially electric power plants	Rugged terrain
Interruption of migration, increased accidental kills	Rail transport of coal	Migratory mammal routes

the factor or factors (e.g., water, nutrients, seedling germination and survival) that limit the production of organic plant material. Limiting factors vary by site. The potential to reestablish a plant cover appears greatest in the Northern Great Plains.

Because they are labor intensive, synthetic fuels facilities located in small communities surrounded by wilderness habitat or in communities that are close to public lands increase the rate and extent of ecological change. Ecological change does not occur at a constant rate as population increases, and the rate of change is different in areas still in their natural state than it is in developed areas. Ecosystems in a developed area have already made an initial adjustment to that development. Expanding development results in only incremental adjustments. Conversely, ecosystems in areas still in their natural states go through large initial adjustments to development. Population increases in wilderness areas compound this problem. For example, legal hunting may be expected to increase proportionately as population increases.[1] But population increases and the introduction of energy facilities also mean habitat fragmentation, potential reductions in the water in springs and seeps, introduction of toxic compounds, illegal shooting of females, outright reduction in food supply, and potential prey-predator imbalances. All these factors in combination accelerate declines in animal populations. Mitigation calls for locating labor-intensive technologies in areas that are already developed or in wilderness areas only when wilderness management and enforcement authority are adequate.

Water-intensive technologies (all conversion facilities, especially electric power generation) located where stream flows are marginally adequate (the San Juan Basin, western Colorado, and to a lesser extent the Yellowstone Basin) will reduce or eliminate sport fish populations. Synthetic fuel technologies are both water and labor intensive. Domestic wastewater discharged into streams where withdrawal is heavy can cause stream eutrophication, leading to changes in plant and animal populations. To the extent that runoff from wastewater impoundments around facilities reaches those streams, further degradation to stream and lake habitat will occur. Mitigation calls for siting water-intensive technologies only where stream flow is adequate, the use of wet/dry cooling at sites where it is inadequate, and strict regulations on energy facility wastewater impoundments and on domestic wastewater treatment.

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[1] If effectively controlled, e.g., through licensing, this need not be the case.

Episodic ground-level sulfur dioxide concentrations from air emissions by electric power plants and oil shale facilities can occur frequently and be high enough to cause chronic and acute damage to plant communities in areas where the terrain is rugged, most notably in southern Utah and western Colorado. Mitigation calls for locating these facilities at other sites (impractical in the case of oil shale) or requiring stricter sulfur control technologies at these sites than elsewhere.

Railroads cause more ecological impacts than any other transportation alternative. Where rail transport crosses migratory mammal routes, changed migration patterns will occur and accidental kills will increase. Mitigation calls for choosing a different transportation technology or constructing passes for animal crossings.

3.5.5 Data and Research Limitations

Data gaps are a problem in nearly all areas of the eight-state region. Vegetation mapping on a uniform basis is only beginning through the use of satellite sensing, and checks with ground data lag far behind. Documentation of animal ranges is often quite dated and very difficult and expensive to maintain. Basic understanding of the reclamation potential of arid lands is inadequate. Streamflow and water quality data are not consistently comprehensive throughout the West, but even greater uncertainty exists in some cases concerning withdrawals for energy, agricultural, and municipal use and that potentially reserved for instream flow. Flow requirements to maintain an aquatic ecosystem in streams is uncertain. A method for measuring habitat fragmentation or determining how much fragmentation causes qualitative changes in an area's wildlife is not available. Probably the most important area of uncertainty concerns the future extent of irrigation and other agricultural withdrawals of land and water from wildlife habitats. A factor of perhaps equal importance is the nature of future directions in the use and management of public lands, which encompass large quantities of wilderness habitat.

3.6 HEALTH EFFECTS

HIGHLIGHTS

• CRITICAL FACTORS

- *Two technological factors can significantly affect the health effects impacts of energy development: the quantity and composition of air emissions, and the quantity and composition of water effluents.*

- Five locational factors can also significantly affect these impacts: composition of the energy resource, population characteristics, topography, meteorological conditions, and existing health care delivery systems.

• PRIMARY STANDARDS[1]

- Synthetic fuel facilities do not cause federal primary ambient sulfur dioxide, particulate, nitrogen dioxide, and carbon monoxide standards to be violated.
- The 24-hour federal primary ambient air standard for particulates is already frequently violated by blowing dust; the addition of fine particulates from surface mining, the transport of coal by trains, and particulate emissions from conversion facilities will exacerbate this problem.
- The federal primary air standard for hydrocarbons will be violated by coal liquefaction, oil shale retorting facilities, and natural gas facilities and by urban sources. Concentrations could be as much as 325 times the standard.
- The federal primary ambient sulfur dioxide standard would be violated in southern Utah and western Colorado by electric power plants equipped with scrubbers that remove only enough sulfur dioxide to meet federal New Source Performance Standards.

• POTENTIAL HEALTH HAZARDS

- Oxidants produced in areas where the violations of federal ambient hydrocarbon standards are greatest can constitute a health hazard.
- If a 3-percent sulfur to sulfates conversion rate is assumed, sulfate levels attributable to energy development is not expected to exceed the concentrations known to cause disease. However, if a 5-percent conversion rate is assumed, sulfate levels at some sites will be high enough to aggravate asthmatics. A conversion rate of 10 percent could result in chronic and acute respiratory disease.

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[1] Primary standards are based on human health criteria and are indicators of health hazards.

- *Any potential health hazard resulting from the release of trace elements and radioactive isotopes in air emissions and water effluents are expected to be minimal except for the release of mercury into aquatic ecosystems containing sport fish.*

3.6.1 Introduction

The effects of energy development on humans depend on the technologies deployed and the site-specific conditions under which development takes place. This section summarizes the technological factors that can cause health hazards and the locational factors that can exacerbate or alleviate these hazards.

3.6.2 Variations by Technologies

As described in Sections 3.2 and 3.3, the energy resource development technologies deployed in our seven scenarios vary in terms of the air emissions and water effluents they produce. These variations determine the potential health impacts of energy development. This section discusses the implications of sulfur dioxide (SO_2), particulate, and hydrocarbon (HC) emissions for human health. Trace and radioactive materials are also covered, but in less detail. The SO_2, particulate, and HC ambient air concentrations resulting from energy development are then related to federal primary ambient air standards, which are defined on the basis of health effects criteria and which, therefore, provide the best available index of the potential for health impacts.

A. Sulfur Dioxide

As indicated in Section 3.2, the synthetic fuels technologies and power generation facilities in our six site-specific scenarios do not cause federal primary SO_2 ambient air standards to be violated. However, in the case of power plants, this is partly because of the level of emission control assumed (flue gas desulfurization systems that remove 80 percent of the SO_2 in the coal). This removal efficiency is in excess of that required to meet federal New Source Performance Standards. If removal efficiency is limited to the amount required to meet these standards, emissions of SO_2 will be higher and, in some cases, will result in the violation of primary standards.

The removal efficiencies required given the ambient SO_2 concentrations that we found are shown in Table 3-25. The 24-hour primary SO_2 standard is violated for the power plant sited at Escalante[1]

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[1] The power plant sited at Kaiparowits in the same scenario does not violate this standard. See Chapter 6.

TABLE 3-25: AMBIENT SO_2 AND PARTICULATE CONCENTRATIONS WHICH RESULT FROM POWER PLANT EMISSIONS WITH THE AMOUNT OF EMISSION CONTROL REQUIRED TO MEET FEDERAL NEW SOURCE PERFORMANCE STANDARDS (NSPS)[a]

Category	Kaiparowits	Escalante	Farmington	Rifle	Gillette	Colstrip	Beulah	Federal Primary Ambient Standards
Removal Efficiency Required to Meet NSPS (%)								
SO_2	0	0	20	0	0	40	40	
Particulates	98.6	98.6	NC	97.1	97.3	NC	NC	
Ambient Air Concentrations ($\mu g/m^3$)								
Particulates								
Annual	2.3	5.8	NC	1.2	1	NC	NC	75
24-hour	29	232	NC	80	22	NC	NC	260
SO_2								
Annual	22	35	13	12	8	7	3.4	80
24-hour	233	1,460	260	175	229	222	292	365

NC = not calculated
SO_2 = sulfur dioxide
$\mu g/m^3$ = micrograms per cubic meter

[a] Power plants produce 3,000 megawatts-electric (MWe) except at Rifle which produces 1,000 MWe.

and Rifle. In both cases, this is caused by plume impaction in complex terrain. Although these concentrations constitute a potential health hazard, few persons are likely to be affected since the cliff walls and peaks impacted by the plume are not likely to be populated.

Sulfur dioxide, by itself, is generally regarded only as a mild irritant. However, when SO_2 and particulates are present simultaneously (as they normally are) or when SO_2 is oxidized in the air to sulfates, SO_2 becomes a health hazard. Every air pollution incident that has resulted in significant human morbidity and mortality has involved a mixture of SO_2 and particulates. Additionally, evidence is accumulating that the sulfates into which SO_2 is transformed pose the greatest potential for harmful health effects. Conversion rates vary from 1 to 20 percent per hour;[1] however, rates of from 1 to 3 percent per hour are commonly used for coal. Table 3-26 gives the sulfate concentrations expected for the site-specific energy development hypothesized (Chapters 6-11) in our scenarios, assuming four different conversion rates. For perspective, sulfate levels known to cause disease are also included in the table. Conversion rates of less than 3 percent generally do not cause sulfate concentrations to be in excess of those which cause disease (Table 3-26). Conversion rates of 5 percent result in concentrations at three sites which exceed those known to aggravate asthmatics, and conversion rates of 10 percent would clearly result in health hazards.[2]

B. Particulates

As indicated in Section 3.2, particulate emissions can vary widely by technology; even with 99-percent particulate removal, electric power plants emit more particulates than any other conversion facility. However, as Table 3-25 indicates, in no case examined does a power plant alone cause primary ambient air standards for particulates to be violated. This includes those cases where the level of control is limited to that required to meet New Source Performance Standards.

However, certain conditions that cause potential health hazards can and do arise in the West. First, exposure to dust in

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[1] U.S., Congress, House of Representatives, Committee on Science and Technology, Subcommittee on Environment and the Atmosphere. *Review of Research Related to Sulfates in the Atmosphere*, Committee Print. Washington, D.C.: Government Printing Office, 1976.

[2] Environmental Protection Agency's Community Health and Environmental Surveillance System relates sulfate levels to the epidemiology of respiratory disease.

TABLE 3-26: SULFATE CONCENTRATIONS AND THEIR HEALTH EFFECTS

Case	Sulfate Concentration ($\mu g/m^3$)			
	1%	3%	5%	10%
Scenario[a]				
Kaiparowits/Escalante	2.2	6.6	11.0	22.0
Navajo/Farmington	0.8	2.4	8.0	16.0
Rifle	1.5	4.5	7.5	15.0
Gillette	0.5	1.5	2.5	5.0
Colstrip	0.9	2.7	4.5	9.0
Beulah	1.1	3.3	5.5	11.0
Health Effects[b]				
Aggravation of Asthma	6-10			
Increased chronic bronchitis	14			
Increased acute respiratory disease	15-25[c]			

$\mu g/m^3$ = micrograms per cubic meter

[a] Based on highest peak concentration including existing ambient concentration (See Chapters 6-11).

[b] U.S., Environmental Protection Agency. *Position Paper on Regulation of Atmospheric Sulfates.* EPA 450/2-75-007. Research Triangle Park, N.C.: National Environmental Research Center, 1975.

[c] Finklea, J.F., *et al. Health Effects of Increasing Sulfur Oxides Emissions*, Draft. Washington, D.C.: U.S., Environmental Protection Agency, 1975. Cited in U.S., Council on Environmental Quality. *Environmental Quality*, Sixth Annual Report. Washington, D.C.: Government Printing Office, 1975, p. 332.

underground mines can be a significant occupational health hazard. Conditions in underground mines in the West will be basically the same as those in the East, where particulates cause lung disease among miners.

Second, 24-hour particulate concentrations already exceed the federal 24-hour primary standard on some days in the West, primarily due to blowing dust. Recorded 24-hour concentrations are 543 micrograms per cubic meter ($\mu g/m^3$) at Kaiparowits, 284 $\mu g/m^3$ at Colstrip, and 488 $\mu g/m^3$ at Beulah. The federal primary 24-hour standard is 260 $\mu g/m^3$. Blowing soil from surface mines, coal dust from rail transport systems, and the added particulates emitted from the stacks of conversion facilities will exacerbate this problem during periods of high winds. Although annual average particulate levels are not expected to exceed the federal annual primary standard, the number of days when the 24-hour primary standard is exceeded will increase due to energy development.

Third, the size and composition of the particulates emitted by conversion facilities help to determine whether they constitute a health hazard. Size and compositional factors are not reflected in simple measurements of total amount emitted or in average concentrations. With 99-percent particulate removal, particles will have a mean diameter of 1-3 microns. These particles can penetrate deeply into the respiratory tract, and about 30 percent of those penetrating will be deposited in the pulmonary alveoli where they can have the greatest adverse effects.[1] In some circumstances, particulates may be aerosols of potentially toxic organic or inorganic substances and may pose a hazard greater than commonly encountered with dust or ash.

C. Hydrocarbons

As indicated in Section 3.2 and summarized in Table 3-27, the federal primary ambient air standard for hydrocarbon is exceeded as a result of emissions from Synthoil liquefaction, TOSCO II oil shale retorting processing, and natural gas production facilities as well as from urban sources. Hydrocarbon emissions from conversion facilities exceed the primary standard by 7 times (natural gas) to 325 times (TOSCO II). Hydrocarbons emissions from liquid processing facilities are difficult to control because they are fugitive emissions coming primarily from valves and fittings. The energy development hypothesized at our six site-specific scenario locations (Chapters 6-11) will result in population increases that will lead to urban hydrocarbon emissions exceeding the primary standard by 1980 at all locations (Table 3-27).

Hydrocarbons by themselves do not produce a direct health hazard, but they do contribute to the formation of oxidants that can damage vegetation and cause irritation to the eyes and throats of humans. They are one of the reactants in the formation of photochemical smog.

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[1] Southern Research Institute, A Survey of Technical Information Related to Fine Particle Control. Springfield, Va.: National Technical Information Service, 1975. PB-242 383.

TABLE 3-27: AMBIENT HYDROCARBON CONCENTRATIONS WHICH RESULT FROM URBAN EXPANSION AND ENERGY FACILITIES ($\mu g/m^3$)

<table>
<tr><th rowspan="2">Source</th><th colspan="2">Peak Concentrations</th></tr>
<tr><th>1980</th><th>1990</th></tr>
<tr><td>Urban Expansion[a] at:</td><td></td><td></td></tr>
<tr><td>Kaiparowits</td><td>NC</td><td>481</td></tr>
<tr><td>Farmington</td><td>750</td><td>871</td></tr>
<tr><td>Rifle</td><td>102</td><td>571</td></tr>
<tr><td>Gillette</td><td>660</td><td>780</td></tr>
<tr><td>Colstrip</td><td>210</td><td>270</td></tr>
<tr><td>Beulah</td><td>120</td><td>180</td></tr>
<tr><td></td><td colspan="2">When Facilities Become Operational</td></tr>
<tr><td>Synthoil Liquefaction at:</td><td colspan="2"></td></tr>
<tr><td>Farmington</td><td colspan="2">21,500</td></tr>
<tr><td>Gillette</td><td colspan="2">25,100</td></tr>
<tr><td>Colstrip</td><td colspan="2">17,200</td></tr>
<tr><td>TOSCO II Oil Shale at Rifle</td><td colspan="2">52,100</td></tr>
<tr><td>Natural Gas Production at Gillette</td><td colspan="2">1,087</td></tr>
<tr><td>Federal 3-hour Primary HC Standard</td><td colspan="2">160</td></tr>
</table>

HC = hydrocarbons
$\mu g/m^3$ = micrograms per cubic meter
NC = not calculated

[a] Urban expansion represents that expected in 1980 and 1990 (except Beulah which is 1995) as a result of the energy development assumed at six sites (see Chapters 6-11).

D. Trace Materials

At least 13 kinds of trace elements are present in coal in amounts ranging from 0.36 to 200 parts per million (see Section 12.6). Of these, beryllium and mercury have been declared hazardous air pollutants; cadmium is on a proposed list of hazardous air pollutants; and selenium, vanadium, and lead are under study. These substances are much more toxic on a by-weight basis than are criteria pollutants. The quantities of trace elements that will be released by synthetic fuels facilities as air pollutants or as water pollutants is not known. For power plants with scrubbers and electrostatic precipitators, the percentages released into the air can be expected to vary from about 1 percent for beryllium, lead, and cadmium to 100 percent for mercury.

Trace elements enter humans via food, drink, and air. Low-level exposure to lead produces subtle nervous system pathologies, and mercury (as an organic mercury compound) is known to affect the central nervous system. Fallout and runoff into lakes will concentrate mercury in aquatic environments where it is converted to the toxic organic form by micro-organisms and taken up by fish.

Trace organic compounds are found primarily in synthetic fuels facilities, especially Synthoil and oil shale retorting. Carcinogenic compounds occur in a number of production streams.[1] Direct exposure to these compounds in process streams is generally not expected, but incidental exposure is possible, depending on water effluent control practices and control of fugitive air emissions. (The likelihood of this occurring is not known.)

E. Radioactivity

Coal generally contains radioactivity in amounts not too different from other minerals. Concentrations are highly variable and range from 0.001 to 1.3 picocuries per gram (see Chapter 12). Radium remains with the ash and therefore is concentrated in it (ranging from 2.1 to 5.0 picocuries per gram).

Health risks from radioactivity originate from exposure to three sources: radioactive particulates in stack emissions, water-borne radioactivity, and radioactive materials in uranium mines and mill tailings. Consumption of the beef and dairy products from cattle that have eaten vegetation exposed to elevated radioisotope levels can also be a source. In the past underground mining for uranium has resulted in occupational exposures resulting in six- to nine-fold increases in lung cancer.[2] However, controls initiated during the past 15 years have reduced radon exposure 10- to 100-fold.[3] Exposures from uranium tailings piles, which contain several thousand times as much radium as ordinary soils, can pose a health risk up to 1 kilometer from the tailings.[1]

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[1] These include polynuclear aromatic hydrocarbons, amines, heterocyclic compounds, and organo-metallic compounds.

[2] Schurgin, Arell S., and Thomas C. Hollocher. "Radiation-Induced Lung Cancers Among Uranium Miners," in Union of Concerned Scientists, ed. *The Nuclear Fuel Cycle: A Survey of the Public Health, Environmental, and National Security Effects of Nuclear Power*, rev. ed. Cambridge, Mass.: MIT Press, 1975, pp. 9-40.

[3] *Ibid.*

Health effects from radioactivity are usually associated with air inhalation and can produce lung cancer. Calculated exposures to the general public from coal fly ash as a result of energy development indicate that the risk of cancer is minimal (one or less additional cancer cases in one million people per year). Doses ranged from 0.1 microrems per year from Uranium-238 to 3.0 microrems per year from Thorium-228 (see Chapter 12).

3.6.3 Variations in Existing Conditions

Several existing conditions are critical to the exposure and response of populations to the pollutants described above. These variables include composition of resources, population characteristics, terrain and atmospheric conditions, and existing health care delivery systems.

A. Composition of Resources

Quantities of trace elements vary greatly over the eight-state region and even within a given locality. For example, coal in the Gillette region contains mercury in amounts ranging from 0.06 to 0.28 parts per million (ppm) (Chapter 9). This is low compared to other coals; Kaiparowits coal is the highest at 0.05-1.2 ppm. The high concentrations of mercury in Kaiparowits coal are of particular concern since the contamination of some species of fish by mercury in nearby Lake Powell already constitutes a health hazard. The lead content of Gillette coals (1.5-40 ppm) is two to three times higher than that of the northern Great Plains lignites.

Estimates of radioactivity in coal are available for only three states in the eight-state area. Those are given in Table 3-28. Montana coal is particularly high in Radium-226.

B. Population Characteristics

Populations susceptible to health problems include the aged, infants, women of childbearing age, and people suffering from pulmonary or cardiovascular deficiencies. Although some general patterns have emerged with respect to older populations, these variables have not been comprehensively reviewed during this first-year assessment. Generally, the Northern Great Plains has the largest population of people over 65 (over 10.6 percent in

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[1] Swift, Jerry J., James M. Hardin, and Harry W. Calley, Potential Radiological Impact of Airborne Releases and Direct Gamma Radiation to Individuals Living Near Inactive Uranium Mill Tailings Piles. Washington, D.C.: U.S., Environmental Protection Agency, Office of Radiation Programs, 1976.

TABLE 3-28: RADIOACTIVITY IN COAL
(pCi/g)

State	Radium-226	Radium-228	Thorium-228	Thorium-232
Utah	1.3	0.8	1	0
Wyoming	0	1.3	1.6	0
Montana	2.9	0.8	0.8	0.8

pCi/g = picocuries per gram

North and South Dakota). New Mexico and Utah have the youngest populations with less than 7.5 percent of the population over 65.

C. Terrain and Atmospheric Conditions

Terrain, temperature, and humidity all contribute to concentrating air pollutants. Rough terrain traps pollutants during atmospheric inversions, and the effects of the sulfur dioxide/particulate mix appears to be most pronounced when prolonged periods of moderately cold temperatures (around 30°F) and high relative humidities (above 70 percent) occur simultaneously. All these conditions occur in the winter in western Colorado; thus, this area is more likely than other areas to experience health problems as a consequence of energy resource development.

D. Existing Health Care Delivery Systems

As indicated in Section 3.3, rural areas and communities impacted by energy resource development frequently lack the infrastructure to support health care facilities and attract doctors. These problems will be especially acute for energy development in remote areas and in areas that experience rapid population growth. Particular problems with health care delivery exist in the rural Southwest such as southern Utah. Some disease problems may be increased unless community health standards are improved. For example, in New Mexico, plague is endemic in rural areas in the northwestern part of the state, and increased human populations will contribute to this community health problem.

3.6.4 Summary of Interactions of Technological and Locational Factors

Some combinations of technological and locational factors can result in health problems. This summary identifies some of these problems and the combinations of factors that cause them. These problems and factors are listed in Table 3-29.

TABLE -23. SUMMARY OF HEALTH EFFECTS PROBLEMS

Health Effects Problems	Combinations of Factors that Cause the Problem	
	Technological	Locational
Primary ambient air standard for Sulfur Dioxide exceeded	Power plants which meet the New Source Performance Standards	Rough terrain in Southern Utah and western Colorado
Respiratory disease	Conversion facilities, especially power plants	Population characteristics
Inadequate health care delivery system	Labor intensity of conversion facilities, fuels facilities	Rural areas, most notably in the Southwest
Mercury concentrations in fish tissue exceed Food and Drug Administration standard	Conversion facilities	Mercury content of coal, proximity to aquatic ecosystems supporting sport fish

Primary ambient air standards are set on the basis of health criteria; violating them poses potential health hazards. Power plants at two scenario sites with sufficient air emission control technologies to meet New Source Performance Standards would violate the 24-hour sulfur dioxide primary ambient air standard. This violation occurs because of plume impaction on rough terrain in southern Utah and western Colorado. Mitigation of this impact will require emissions removal at higher efficiencies.

Respiratory disease in susceptible populations is a threat as a result of the sulfur dioxide and particulate emissions from conversion facilities, especially electric power plants. Sulfate concentrations approach those causing disease at a 3-to-5 percent sulfur dioxide-to-sulfates conversion rate and can be expected to increase the incidence of disease in the aged, infants, and persons with pulmonary and cardiovascular deficiencies.

Locating labor-intensive conversion facilities in rural areas such as the Southwest will result in population increases that exceed the capacity of health care delivery systems.

Burning coal with a high mercury content in the vicinity of aquatic ecosystems that support sport fish may increase the mercury content of fish to levels that exceed those recommended by the Food and Drug Administration for safe human consumption. Mercury concentrations in some biota in Lake Powell in the vicinity of energy development at Kaiparowits, Utah currently exceed these standards. And the incremental addition from the combustion of coal in the area would aggravate this problem.

In addition, occupational health hazards in western coal mines, while similar in all underground coal mines regardless of location, will likely be a significant problem. Mortality as a result of accidents and respiratory disorders as a result of particulate inhalation can constitute significant health problems. Adequate ventilation and roof support in these mines can alleviate the problem.

3.6.3 Data Limitations

Our examination of health effects has been limited both by data and the current state of basic research. More data are needed on emission rates of potentially toxic materials from each of the energy technologies examined. Also, these emission rates need to be traced along exposure pathways using results reported in existing health effects literature. Knowledge is limited in such areas as distribution of fine particulates, conversion rates of sulfur dioxide to sulfates, and hydrocarbon stream composition in synthetic fuel plants. Also, effects of exposure on the characteristic populations of western regions under circumstances that occur there are highly speculative.

3.7 TRANSPORTATION

HIGHLIGHTS

• CRITICAL FACTORS

- *Two technological factors can affect transportation impacts: capital intensity and water requirements.*
- *Three locational factors can affect these impacts: the capacity of existing transportation systems, the location of existing systems in relation to energy resources, and the availability of water.*

• CAPITAL AND OPERATING COSTS

- *Rail systems are less capital intensive than slurry systems, but both systems require large investments.*
- *A higher proportion of the costs of a rail system are operation costs.*
- *DC transmission is relatively more economical than AC for large volumes and long distances; AC is more economical for smaller volumes and shorter distances and when the power is routed to several destinations.*

• FLEXIBILITY

- *Rail systems are more flexible than slurry systems in terms of fluctuating demands, delivery to numerous destinations, and transport of other commodities.*

• WATER REQUIREMENTS

- *Approximately 770 acre-feet of water are required for each 1 million tons of coal transported by slurry pipeline.*
- *By the year 2000, scenario slurry pipelines originating in the Northern Great Plains will require more than 300 thousand acre-feet per year or 23 percent of the water required for energy development in that area.*

• EXISTING CAPACITY

- *Existing gas pipelines in the Four Corners area are expected to be adequate to transport both natural and synthetic gas through the year 2000; existing oil pipelines are not.*

- *Existing oil pipelines in the northern Great Plains are expected to be adequate to transport both crude and syncrude through the year 2000; existing gas pipelines are not.*

- *New transmission lines will be required for almost all new electric power plants built from the present to the year 2000.*

3.7.1 Introduction

The work done in the first phase of this study verifies what has been found in a number of previous studies: that large-scale resource development in the western U.S. will require substantial new investments in transportation facilities. As reported in Chapter 12, capital costs for transportation may total more than $40 billion by the end of the century, equivalent to more than 25 percent of the total cost of the energy facilities. In addition to the impacts this investment will have on the national economy, transportation facilities can produce locally significant environmental impacts along their rights-of-way. These impacts include noise, accidents, visual intrusion, and barriers to human and animal mobility. The factors that vary by technology and by site and that determine the extent of such impacts are discussed in this section.

3.7.2 Variations Among Technologies

The choices among transportation modes are limited by the choices among energy conversion technologies. The first choice to be made is whether to convert the resource at or near the mine site (the "mine-mouth" option) or ship it to the demand center in raw form (the "strip and ship" option). If the mine-mouth option is chosen, several final fuel forms are available (liquids, gases, and electricity), each with specific transportation modes available. The present discussion is organized around the choice of mode, since each has certain characteristic impacts.[1]

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[1] As part of the study, the Center for Advanced Computation at the University of Illinois at Urbana-Campaign undertook a "Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission" study under a subcontract with the University of Oklahoma. The final report of the study is appended to this report (see Appendix B).

A. Export of Solids: Rail versus Slurry

We have examined two types of solid fuels: coal and uranium.[1] Since substantially larger amounts of coal production are anticipated (in terms of weight), attention has been focused on that resource. The two leading prospects for coal transport are rail and slurry pipeline.[2]

More than 90 percent of the total cost of a slurry system is capital-related, while operating costs form a higher proportion for a rail system.[3] This large capital-operating cost imbalance means that slurry pipelines are economical alternatives to rail systems only when their capacities can be fully used. Consequently, slurry pipeline operations need firm, long-term contracts and throughput rates close to design specifications to operate economically and efficiently.

The water required by slurry lines (77 acre-feet per million tons of coal) will make additional demands on already short supplies in some regions of the West. Although closed-loop systems (where the water is returned in another pipeline) and the use of petroleum products[4] instead of water have been proposed, neither is considered an economically viable alternative at present.

Rail systems are more flexible than slurry pipelines in their ability to meet fluctuating demand levels and in their potential to deliver to a variety of geographic locations. Moreover, rail lines can carry other kinds of freight when not used to capacity by unit coal trains.

Slurry pipelines avoid a number of the environmental impacts of rail systems. Railroads are noisy, disrupt automobile traffic, and can collide with automobiles in urban areas and with wildlife in rural areas. Also, some people object to the visual intrusion of rail lines on scenic vistas.

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[1] Although oil shale may be mined as a solid, export of the shale before extracting the kerogen is not considered practical because of the large volume of shale that would have to be transported.

[2] Although western coal may eventually be transferred to barges, water transport is generally not available west of the Mississippi.

[3] The comparative economics of the two systems depend, to a great extent, on the cost of restoring existing rail lines. This cost is discussed later in this section.

[4] The petroleum product would be burned, along with the coal, in this alternative. To the best of our knowledge, no one has seriously proposed a closed-loop system.

At the railroad usage levels anticipated in the regional scenario,[1] noise impacts will be substantial for many people. More than one million people live within 1 mile of one Montana-to-Chicago route and, as calculated in Section 12.9, noise produced by a single unit train can be annoying up to 1 mile from the track. In the case of traffic disruption, the rail usage anticipated in our Nominal Case calls for 43 round trips per day to the Chicago area. If 43 round trips per day are sent along a rail line at 20 mph, the chance of a grade crossing being blocked at any given time will be one in six. One obvious solution to the problem would be to build overpasses rather than grade-crossings. However, this solution would entail extra expense (not estimated in this study), and decisions would have to be made about the sharing of those costs.

Another solution to the crossing problem (as well as the noise problem) would be re-routing main lines away from population centers. Again, the uncertainties to be resolved are cost and sharing of cost. Interestingly, railroad officials recently announced voluntary re-routing of unit trains away from the cities of Colorado's Front Range.[2]

Environmental impacts of slurry pipelines are different in kind and are almost entirely related to their use of water. The water must be treated at the end of the line before being re-used or discharged into a river. Also, spills can occur as a result of failures in joint welds, pipe sections, and pumping station equipment. With the exception of pumping stations, repairing such leaks will normally require flushing a substantial portion of the line and thus discharging a large amount of the coal and water mixture.

At the national level, western energy development has a greater proportional impact on railroads and railroad equipment manufacturing than on any other industry.[3] In physical terms, by the year 2000, Nominal Case development would require more than 500 unit trains containing more than 2 million tons of steel and costing $2.1 billion. This is in addition to the 11.8 million tons of steel in the new and upgraded track previously mentioned (with comparable quantities of wood, concrete, gravel, etc.). Overall, railroad equipment manufacturing would have to grow about 1 percent per year faster than it otherwise would, given the added impulse of the Nominal Case level of energy resource development in the western U.S.

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[1] More than one hundred 100-car unit trains leaving the Powder River Basin daily by the year 2000.

[2] Brown, Fred. "Long Coal Trains Won't Bisect Region." Denver Post, October 30, 1976.

[3] EPA's Strategic Environmental Assessment System (SEAS) was used to investigate materials and equipment availability. See Booz, Allen and Hamilton, Inc. Strategic Environmental Assessment System, Executive Summary, for U.S., Environmental Protection Agency. Bethesda, Md.: Booz, Allen and Hamilton, 1975. Contract No. 68-01-2942 and Section 12.4.8 of this report.

B. Export of Electricity: AC versus DC

Electrical transmission avoids many of the problems mentioned above and, in some ways, constitutes even less of a barrier to animals than do above-ground pipelines. Like slurry pipelines, electrical transmission costs are heavily weighted toward initial capital investments, and the economics of such lines are predicated on full-capacity utilization. The concept of mine-mouth electrical generation for export implies that there are almost never any existing transmission facilities.

The two major technological alternatives available for electrical transmission are alternating current (AC) and direct current (DC). AC has relative advantages when smaller quantities of power are sent over shorter distances (as compared to DC applications). AC also allows more flexibility in terms of delivering power to many destinations simultaneously. These differences arise mainly from the fact that DC terminal installations are more complex and expensive. In other respects, DC seems to have the advantage: they can carry significantly higher line loads, have lower transmission losses, result in less noise, and require shorter supporting towers. Still, the voltages being contemplated for bulk energy transmission (800 kilovolts) produce unique phenomena (e.g., some electrostatic effects) with which little operating experience has yet been gained.[1]

Because of their height, transmission lines have more of an aesthetic impact than do other transport modes.

C. Gas and Liquid Pipelines

Pipelines will be used when petroleum and natural gas are exported from the region in raw form, or when coal is liquefied or gasified within the region. From both the economic and environmental points of view, the operating characteristics of these pipelines are more similar to slurry pipelines than to railroads.

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[1] Further details may be found in Section 12.7 of this report and Section IV of "Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission", in Appendix B.

3.7.3 Variations Among Existing Conditions

Certain locational characteristics, which vary in the West, partly determine the impact of a technology on a site. The key questions are whether the capacity of existing transport links is adequate and is in close proximity to developable energy deposits and, in the case of slurry pipelines, the extent to which water is available.

A. Existing Capacity of Transport Links

Obviously, extraction (and, to some extent, processing) must be done wherever the minerals are found. More often than not, the deposits are located far from established populations centers and their associated transportation networks. The following discussion summarizes present capacity by area for rail systems, gas and oil pipelines, and electrical transmission lines. At present there is no excess slurry pipeline capacity.

1. Rail Systems

In the eight-state study area, rail facilities are especially sparse around the Four Corners area. In that region, the distance from coal deposits to the nearest rail trunk line may often exceed 150 road miles. Due to denser populations and greater agricultural production, rail links in the Great Plains have been developed more extensively.

The capacity and quality of rail lines presents the most problematic issue in the study area's transportation system. Comprehensive, systematic data are not available on how much coal could be carried over the current rail lines or how capacity varies by region. Much of the nation's rail lines have not been maintained to normal standards, and unit trains will require better-than-standard track for high-speed operation. One estimate of reconstruction costs is $3.3 billion.[1]

However, even if all existing lines are upgraded for unit trains, the volumes of coal in the regional scenario will necessitate the building of new main lines. There is some disagreement as to when existing rail line saturation would occur, but assuming that 25 million tons of coal per year could be handled on one set of double track, some 18,000 miles of additional track would be required by 2000, at a cost of $5.5 billion. However, any excess carrying capacity of new and rebuilt rail lines would be available for other commodity shipments, which is an advantage not shared by other transport modes considered here.

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[1] U.S., Federal Energy Administration. Project Independence Blueprint, Final Task Force Report, Analysis of Requirements and Constraints on the Transport of Energy Materials, Vol. 1. Washington, D.C.: Government Printing Office, 1974.

2. Gas and Oil Pipelines

Existing gas pipeline capacity from the Rocky Mountain area (also serving the Four Corners area) is adequate for the synthetic gas and natural gas developments hypothesized for the area through the year 2000. Two major interstate gas pipeline companies have pipelines that currently traverse the Rocky Mountain resource area; these have a total yearly capacity of 2,341 billion cubic feet (bcf), exclusive of added compression and looping which would increase the capacity (see Chapter 12). Except for short pipelines to tie in with these existing trunk lines, no new pipelines should be required to transport the projected gas production in the Rocky Mountain area.[1] In the Northern Great Plains, gas pipeline capacity may be inadequate. A nominal demand scenario projects that 201 bcf of gas in 1990 and 3,429 bcf in 2000 will be produced in the Powder River Coal Region. One major gas pipeline with a capacity of 56 bcf per year currently traverses the Powder River Region.

Existing oil pipeline capacity is adequate in the Northern Great Plains and inadequate in the Rocky Mountains. Assuming the Nominal Case level of development, 142 thousand barrels per day (bbl/day) should be produced in the year 2000 in the Powder River area of the northern Great Plains. Existing capacity there is 620 thousand bbl/day. In the Rocky Mountain area, 3.9 million bbl/day should be produced by 2000, and existing capacity without looping is 260 thousand bbl/day.

Assuming that existing oil and gas pipeline capacities will be available for a shift from natural gases and liquids to synthetics, the Nominal Case development projections[2] will require new gas pipelines of 3.3 trillion cubic feet per year total capacity by the year 2000 from the Northern Great Plains at a cost of $2.8 billion (1974 dollars). The same case also requires new oil pipelines with a total capacity of 3.6 million bbl/day from the Rocky Mountain area at a cost of $684 million (1974 dollars).

3. Transmission Lines

Generally speaking, each mine-mouth power plant will need a new transmission line to connect it with the distribution network at the load center. Substantial transmission capacity links the

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[1] This assumes nominal demand; excess capacity would result from low demand and a shortage in the case of our low nuclear availability scenario (see Chapter 12 for scenario details).

[2] See Chapter 12 for scenario details.

Four Corners area, Arizona, and Los Angeles; other routes are less developed.[1] Nominal Case development, as estimated in this Technology Assessment, would call for 13,000 new miles of 2,200-megawatt-electric lines in the region by the year 2000.

B. Water Availability for Slurry Pipelines

The viability of a slurry pipeline depends on the availability of water at the shipping point. In general, more water is available from the Upper Missouri River Basin than from the Upper Colorado River Basin. However, the amount of water available from specific areas depends on technical, economic, and legal factors. For example, interstate compacts may restrict the export of water (through the pipeline) out of a river basin. Nevertheless, equivalent amounts of water may be consumed in generating electricity for transmission out of the area, because this is not considered an export of water.

3.7.4 Summary of the Interactions Among Technological and Locational Factors

Certain combinations of technological and locational factors can cause transportation impacts to be more or less severe.

Water availability partially determines the viability of a slurry pipeline. Both because water is in short supply (see Section 3.3) and because of unresolved water rights and allocation questions, the Upper Colorado River Basin is less likely to be able to support slurry pipelines than is the Upper Missouri River Basin. However, the Upper Missouri developments might still need more slurry pipelines than the Upper Colorado developments because of greater demand for coal.

Existing gas pipeline capacity is adequate for projected development to the year 2000 in the Rocky Mountains but inadequate in the Northern Great Plains. Oil pipeline capacity is the reverse case. Efficient utilization could require synthetic gas production expansion in the Rocky Mountains at the expense of synthetic oil production. The reverse is true in the northern Great Plains.

3.7.5 Data Adequacy

One of the most controversial issues in energy transportation is the choice between unit trains and slurry pipelines.

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[1] Energy Resources Co. *Preliminary Assessment of the Economic and Environmental Impact of Alternative Demand/Supply Scenarios for Electricity in the Southwest*, Draft Final Report, for U.S., Environmental Protection Agency. Cambridge, Mass.: Energy Resources Co., 1976.

Analysis of this issue would be greatly aided by resolution of certain questions: (1) What are the costs of building, upgrading, and operating these systems? A key element of that evaluation will be an assessment of the capacity and state of repair of current rail lines. (2) What are the operating characteristics of slurry pipelines (particularly their adaptability to fluctuating demand) and the consequences of accidental breaks? Announced projects would ship five times as much coal four times as far as the largest currently operating line (the Black Mesa line in Arizona and Nevada). Also, new problems may arise in the process of scaling up. (3) How much water is available for slurry lines? This is connected with the entire water availability question in the West.

Similar questions may be asked in regard to AC versus DC power transmission. In the high-voltage ranges being proposed, little operating experience is available for use in judging the technical, economic, and environmental merits of these lines.

Finally, the economic modeling of regional energy demand has considered geographic factors only on a crude basis. For example, the Stanford Research Institute's model breaks the nation into a few regions,[1] and energy is hypothetically shipped to their "centroids".[2] Until such analyses are refined, not much confidence can be placed in projections of energy flows, directions, and modes.

3.8 AESTHETICS AND NOISE

HIGHLIGHTS

- **AESTHETICS**
  - *Many aesthetic impacts are subjective and, therefore, vary among individuals.*
  - *Aesthetic impacts from energy developments near national parks, forests, monuments, isolated areas, and areas in a natural state will be relatively larger than in most other areas, and more persons are likely to perceive aesthetic problems in these areas.*
  - *Strip mines, conversion plants, transmission lines, and trains will produce visual impacts, including visual intrusions, opaque plume, and reductions in visibility.*

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[1] There are only two production regions for the mountain West.

[2] A centroid of a region is calculated as the point which minimizes the average distance to all other points in the region.

• NOISE

- *Noise impacts will occur within one-half mile of rail lines where the noise level will be above 55 decibels. Depending on the route, these impacts could affect a large number of people.*

3.8.1 Introduction

Most of the aesthetic impacts from energy development will result from physical alterations and thus might be considered in such impact categories as air, water, and quality of life. However, individual reactions to such changes are primarily subjective and cannot be captured merely by describing the physical changes caused by energy development.[1] Personal values significantly affect an individual's evaluation of aesthetic appeal and, ultimately, what constitutes an aesthetic impact.

Except for noise, aesthetic impacts have not received much attention on a site-specific basis during the first year of this study. This is due to the limited availability of information on aesthetic considerations pertaining to energy development activities. Thus, the following sections first identify some potential aesthetic impacts of the different technologies and the different site conditions in the West, then summarize important technology and site interactions. A fourth section discusses data and information gaps that limit aesthetic impact analyses.

3.8.2 Variations by Technologies

Long-time residents of the West hold certain non-material attitudes about their scenically spectacular region. These attitudes often lead westerners to perceive strip mines, energy conversion facilities, stacks, plumes, transmission lines, etc., in a different manner than newcomers who are to be employed by the technological activities. While no data exist to compare the aesthetic impacts of different energy development technologies, several generalizations can be made. For example, the most prominent land-related impacts result from surface mining, which can alter the vegetation, color, and topographic character of the land. Thus, the extent of land disturbed and the practices used to reclaim it are critical from an aesthetic viewpoint.

As discussed in Chapters 6-12, energy conversion plant stack plumes will be visible at substantial distances and will, under certain meteorological and topological conditions, reduce the average visibility by as much as 12 percent (even more during inversion episodes). Also, pollutants could alter the natural coloration of the sky in some areas, thus affecting the contrast of natural features and formations against the skyline.[1]

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[1] For a discussion of this point see White, Irvin L., _et al._ _First Year Work Plan for a Technology Assessment of Western Energy Resource Development_. Washington, D.C.: U.S., Environmental Protection Agency, 1976, pp. 4-157 to 4-160.

Finally, energy development in each of the scenarios will increase levels of traffic (highway and rail) and will introduce new stationary sources of noise as well. At low levels, noise impacts are essentially aesthetic; at higher levels, noise can also affect health.

The amount of noise generated will depend on the particular types of equipment being used. Among transportation sources, trucks and unit train engines produce noise levels about 95 dB (decibels), resulting in an annoyance level (55 dB) within one-half mile of roads and railroad lines. Equivalent noise levels are generated by such stationary sources as coal car shakers, rock drills, cooling towers, and pulverizers. However, moving sources will generally produce more extensive impacts than stationary sources because they reach more people.

3.8.3 Variations by Existing Conditions

Aesthetic land impacts will vary according to the existing geographic and topographic conditions at the facility site. In addition, some of these impacts may be avoided or reduced, depending on the regulatory and enforcement practices of the state where the energy development occurs. Most of the western states require regrading to simulate the original contour of the land which, in most cases, means shaping the spoils to form a gently rolling surface. This practice not only reduces the aesthetic impacts of surface mining but has been used to improve the aesthetics of an area by adding distinctive new relief characteristics and allowing the development of "non-native" vegetation. Of course, the areas most susceptible to aesthetic impacts are those close to recreational or national sightseeing areas valued by long-time residents for aesthetic appeal (such as southern Utah and western Colorado).

Where new site access roads make wilderness areas more accessible, the increase in off-road vehicle use could lead to further destruction of plant life and encourage illegal activities such as poaching or indiscriminate killing of non-game animals. This is a potential problem at all energy development sites in the West, but serious negative impacts are most likely to occur at such places as: Beulah, North Dakota, where the geologic fragility and high recreational potential of the badlands to the west of the area make them extremely vulnerable to overuse; Escalante, Utah, which is surrounded by national parks, forests, and recreation areas, all within easy driving distances from area population centers; and Rifle, Colorado, which is also in close proximity to several national parks and forests and where certain heavily used areas are already beginning to show visible signs of deterioration.[1] Further, as discussed previously, activities related to energy extraction and production can stress wildlife populations. Intentional or inadvertent harassment can heighten the potential for the elimination or reduction of species on a local basis.

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[1] U.S., Department of the Interior, Bureau of Land Management. *Final Environmental Statement: Proposed Kaiparowits Project*, Chapters III-VI. Salt Lake City, Utah: Bureau of Land Management, 1976.

Noise impacts will depend primarily on the distances between sources and populations. Thus, those people living closest to the energy facilities will experience the highest average sound levels, but, as noted, railroads will affect the greatest numbers of people. For example, more than one million people live within one mile of a railway main line from Montana to Chicago. Topography and foliage will modify noise impacts to a degree. For example, valleys tend to entrap noises generated within them, and dense brush and forests absorb sound waves quickly.

3.8.4 Summary of Interactions of Technological and Locational Factors

The blue skies and long-range visibility of the western states are highly valued, both for their intrinsic appeal and for their enhancement of the scenic beauty of parks, monuments, and protected sites in the region. Currently, many portions of the study area have average visibilities of 65-70 miles, and some places in southern Utah and northern Arizona allow clear visibility up to 100 miles. Thus, any reduction in long-range visibility at particular sites will probably be considered a significant negative aesthetic impact by both residents and tourists. However, a potentially much larger aesthetic impact is the cumulative effect of all the postulated developments on visibilities throughout the region. This impact cannot be estimated at present, but it could become a critical aesthetic consideration.[2]

Regardless of reconditioning efforts, the expected net change in appearance of a mining area may be ascertained by some as a negative aesthetic impact simply because it is different from what existed "naturally". Problems in reclaiming mined land may reduce the variety of vegetation in some more arid areas of the West (particularly southern Utah, northwestern New Mexico, and western Colorado), thus contributing to the disappearance of certain wildlife species. Similarly, the dewatering of aquifers and the infiltration of aquifers, springs, and streams by waste pond leachates will produce impacts on both aquatic species and wildlife that depend on these water sources. These impacts could become major problems at some sites. For example, in the Colstrip area in southeastern Montana, portions of some major aquifers lie within or just below a coal seam and, depending on the composition of the overburden, oxidation of the spoil material returned to a strip mine may result in the release of contaminants to water recharging area aquifers.

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[1] Todd, J. "We're Losing the Wild in the Wilderness." Colorado Outdoors, Vol.25 (March/April 1976), pp. 10-11.

[2] See Josephy, Alvin M. "Kaiparowits: The Ultimate Obscenity." Audubon, Vol. 78 (March 1976), pp. 64-90.

There is an obvious, direct link between the above ecological problems and aesthetic impacts, especially in recreational and "wilderness areas". Most people highly value the diversity and well being of wildlife and vegetation in national parks and pristine places. Thus, any reduction or loss of wildlife and vegetation in such areas caused by development-related pollution or aquifer dewatering will have negative aesthetic impacts on area visitors.

Other aesthetic impacts will result from development-related population increases in areas with low populations currently. These increases will obviously increase the number of visitors to primitive or otherwise pristine places, which can lead to deterioration of the areas through acts of destruction, vandalism, and heavy use. General overuse and congestion appear to be major sources of visitor dissatisfaction in primitive areas. For example, the Escalante, Utah and Gillette, Wyoming areas could experience population growths of well over 400 percent by the year 2000. The eastern part of the Escalante area is virtually uninhabited at present and would be highly susceptible to such impacts. At Gillette, both the pristine and the semi-pristine (the isolated rural or small town) environments hold aesthetic values for area residents. The urbanization issue in Wyoming and much of the West is particularly contentious because of residents' desires to keep their small town atmospheres.[1]

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[1] See: University of Montana, Institute for Social Science Research. *A Comparative Case Study of the Impact of Coal Development on the Way of Life of People in the Coal Areas of Eastern Montana and Northeastern Wyoming*. Missoula, Mont.: University of Montana, Institute for Social Science Research, 1974; and Northern Great Plains Resources Program, Socio-Economic and Cultural Aspects Work Group. *Socio-Economic and Cultural Aspects of Potential Coal Development in the Northern Great Plains*. Discussion Draft. Denver, Colo.: Northern Great Plains Resources Program, 1974, pp. 37-73.

As noted previously, energy development-related noise increases cause aesthetic impacts in nearby communities. To some long-time residents, both the intermittent and continuous sounds will be displeasing, annoying, and possibly disturbing to typical patterns of behavior and sleep. In an area such as Rifle, Colorado, where a larger than normal fraction of the population is of retirement age, the noise created by an energy development could be especially annoying. The fact that retirement-age people have moved into this area seems to indicate a desire to get away from the disturbing effects of higher-paced life elsewhere and spend their retirement years in relatively calm, quiet surroundings. Significant increases in noise levels would be especially undesirable under such circumstances.

3.8.5 Data and Research Limitations

Since aesthetic impacts are largely subjective, they are both difficult to assess and open to considerable disagreement among interested parties. Some impacts are rather straightforward in relation to their aesthetic content; for example, the presence of untreated sewage or waste in a lake or stream. Others, such as local attitudes about a newly constructed energy facility's effect on the surrounding landscape, can only be identified through actual surveys of resident perceptions and attitudes. Only a minimum of reliable information exists for impacts in the latter category, and thus information on aesthetic preferences generally must be extrapolated from available survey material for the western states. However, such data usually have not been structured to systematically include aesthetic attitudes with regard to energy development, are not available for the scenario sites included in this Technology Assessment, or are related to a single aesthetic category such as transmission line rights-of-way.

3.9 SUMMARY

This summary identifies those technological and locational factors that are particularly significant in either choosing or evaluating a technology-location combination. It also summarizes differences in impacts that can generally be expected given different technologies, locations, or technology-location combinations.

3.9.1 Technological and Locational Factors that Cause Impacts

Table 3-30 lists the impact-causing factors identified in Sections 3.2-3.8 as being significant within any single impact category. Note that several factors are listed in several impact categories. In the technological factor column, the labor intensity of technologies and the extent to which environmental control technologies are employed determine the nature and severity of a variety of kinds of impacts. Locational factors

TABLE 3-31: IMPACT CAUSING FACTORS

Impact Category	Technological Factors	Locational Factors
Air	Quantities of emissions The effect of control technologies Labor intensity	Coal characteristics Terrain and dispersion potential Community size and location Ambient air quality and state air quality standards
Water	Water requirements Effect of wet/dry cooling Effect of labor intensity Water effluents From facilities From urban sources Aquifer disruption	Water availability Coal characteristics Ambient water quality Aquifer characteristics
Social/Economic/Political	Labor intensity Scheduling Capital intensity	Community size and location Capabilities of existing institutions Historical out migration Characteristics of local labor force Local financial conditions Culture and lifestyle of an area
Ecology	Land use, Labor intensity, Water requirements, Control of effluents, Air emission, Transportation system	Ecosystem stability and resiliency Climate, Soils, Plant and Animal communities Character of existing land use patterns, Stream flow
Health	Sulfur Dioxide Particulates, Hydrocarbons Trace materials Radioactivity	Coal characteristics, Population characteristics, Terrain, Existing health care delivery systems
Transportation	Rail vs. Slurry, Oil and Gas Pipelines, Transmission: AC vs. DC	Existing transportation capacity Water availability for slurry pipelines
Aesthetics and Noise	Visibility reduction, Land use, Noise intensity, frequency, and duration	Local attitudes, Topography Existing regulatory and enforcement problems, Accessibility to wilderness areas

that affect several categories of impacts are community size and coal characteristics.

The labor intensity of a technology affects: air quality; water use; water quality; the ability of communities to provide services; the extent of political disruptions caused by changes in the newcomer-to-oldtimer relationships; the extent to which plant communities and wildlife habitat will be used and abused; and the ability of health care delivery systems to provide health services (and thus the overall health of the population at a site).

Similarly, the extent to which environmental control technologies are employed greatly affects: air quality (in the case of air emission controls); water use (in the case of cooling options); and water quality (in the case of wastewater control technologies). Air, water use, and water quality control technologies partially determine the changes expected in terrestrial and aquatic ecosystems, the health of the population, and aesthetic impacts such as visual impairments (plumes and structures).

Community size affects changes in: air quality (when development is initiated, air quality changes rapidly in small communities); water quality (small communities often do not have adequate sewage treatment plants nor the resources for expanding them); the services available and the institutional and financial capacity to expand these services; the extent of political disruptions caused by changes in the newcomer-to-oldtimer ratio; health care capacity; the proximity and extent of transportation links; and the local attitudes toward aesthetic impacts.

Coal characteristics, which vary widely in the eight-state area, affect: air quality (as sulfur and ash content vary); water use (as moisture and seam thickness vary); water quality (effluent streams vary in composition in accordance to variations in coal composition); the extent to which plant communities and wildlife habitat is degraded and eliminated (as seam thickness and thus land use vary); and health impacts (as the trace element composition, sulfur, and ash content vary).

3.9.3 Export Versus On-site Conversion

Two major choices are available to policymakers: mine and ship the coal out of the region to be converted elsewhere (this choice is not available in the case of oil shale and is the rule in the case of uranium), or mine and convert the resource to another fuel form on-site, in which case the choice is among conversion facilities. This section very briefly summarizes some of the consequences of those choices and how locational factors can affect them.[1]

A. Coal Export

Our analysis indicates that mining and exporting coal minimizes the negative air quality, water, ecological, social, political, and health impacts experienced at a site. Air emissions from mining can be negligible, if proper dust suppression techniques are used; and emissions[2] from urban sources associated with mining are much less (because population increases are less) than is the case with conversion facilities. Even when intensive irrigation is assumed, water use for reclamation is one-tenth that required by a conversion facility. Degradation and elimination of terrestrial plant and wildlife communities will result from surface mining, but the population induced ecological impacts caused by the increases associated with labor intensive synthetic fuels facilities are at least as great as those induced by surface mining. Because the labor intensity of mining is low (especially for surface mining), social impacts resulting from inadequate services and facilities and political impacts caused by the influx of newcomers are less. Since air and water quality remain virtually unchanged, health hazards except for occupational health, are unlikely. This is not to say that mining does not have negative impacts. For example, aquifer systems can be altered and underground miners will be exposed to occupational health hazards.

Mining for export may also minimize positive impacts. Tax revenues, employment potential, and income benefits associated with capital- and labor-intensive conversion facilities are exported along with the coal.

B. Mine-Mouth Conversion

Synthetic fuels facilities have many impact-causing factors in common, and these factors are substantially different from those associated with electric power plants.

Synthetic fuels facilities result in fewer air quality problems than electric power generation because emissions are considerably less (hydrocarbon emissions from coal liquefaction and oil shale retorting facilities are an exception). The hypothetical coal synthetic fuels facilities at our sites do not cause Federal ambient air standards or Class II Nonsignificant Deterioration increments to be exceeded. Power plants in our scenarios regularly violate Class II increments even when high levels of pollutant removal by air emission control technologies are assumed. When control technologies are lower (at levels which would meet New Source Performance Standards), ambient standards are violated.

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[1] The costs/risks/benefits of these options at various sites are now being quantified and compared.

[2] Fugitive dust may be a problem and will be examined in more detail, including rail transportation of coal as a source.

Similarly, water use by electric power plants is considerably higher than that of synthetic fuels facilities (unless power plants use wet/dry cooling, in which case they are similar). Lurgi gasification requires less water than any other conversion technology. In the central Rocky Mountains and Southwest, where water is both scarce and water rights questions major, water consumption may very well be the determining variable in choosing a conversion technology. Since air quality is also more of a problem in these areas (due to the terrain, dispersion potential, and, in the case of Colorado, state ambient air quality standards), synthetic fuels facilities may be a more desirable choice for the Southwest and central Rocky Mountains than power plants. If electric power plants are sited in these two areas, air emission control technologies may have very high removal efficiencies and wet/dry cooling may have to be employed.

Although all conversion technologies are more labor intensive than mining, synthetic fuels facilities are substantially more labor intensive than electric power plants. This means that the social, economic, and political and ecological impacts of electric power plants are likely to be less than those of synthetic fuels facilities.[1] Moreover, electric power plants offer the biggest increase in tax base for the least labor intensity. Therefore, fewer increases in services and facilities will be required and the social, economic, and political problems caused by an influx of newcomers will be mitigated. A lower labor intensity also means less direct land use and less degradation of plant communities and wildlife habitat.

C. The Effect of Locational Considerations

The effects of conditions at a specific site cut across all the generalizations stated above either to worsen or mitigate impacts. Those conditions that affect air quality, water, and ecological impacts generally vary according to three sub-areas in the eight-state study area: Northern Great Plains, Rocky Mountains, and Southwest. However, social, economic, and political impacts are also caused by factors that range across these regional boundaries; that is, impacts are sensitive to other than physical factors. Community size is probably the single most important of such variables, and small communities are found throughout the eight-state study area. Community size affects the capacity of the public and private sectors to provide services, the nature of the local labor force, and the extent to which oldtimers are likely to be displaced by newcomers in the political power structure. State impact mitigation programs also determine a community's ability to respond to rapidly escalated demands for services and facilities, and such programs vary from state to state.

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[1] As noted above, air emissions and water requirements are greater for electric power plants. These differences also have to be taken into account in the analysis of tradeoffs among technological alternatives.

CHAPTER 4

POLICY PROBLEMS AND ISSUES

4.1 INTRODUCTION

In Chapter 14 of this report, seven categories of problems and issues are discussed: water availability and quality, reclamation, air quality, growth management, housing, community facilities and services, and development of Indian-owned resources. However, the identification and definition of these categories was initially undertaken before the results of the impact analyses summarized were available. The problems and issues that were discussed were those that are widely perceived to be important.

We have now had an opportunity to relate problems and issues to the consequences of western energy resource development. As discussed in Chapter 2 of this report, the identification of both real and anticipated impacts is the beginning point of policy analysis because it raises questions about which development policies might contribute to desirable impacts and which might help mitigate or eliminate undesirable ones. Additionally, the impact analysis increases our knowledge of the significance of individual policy issues--e.g. the severity, magnitude, timing, and interrelationships among policy issues.

This chapter summarizes four categories of policy problems and issues and explicly relates them to the impact analysis results summarized in Chapter 3. These categories are water, air planning and growth management, and reclamation. During the remainder of the project, more attention will be paid to identifying the parties-at-interest to these issues,[1] alternative policies and associated costs, risks, and benefits, and implementation strategies.[2]

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[1] Chapter 13 presents a preliminary overview of the energy policy system and identifies many of the parties-at-interest likely to be affected by western energy development.

[2] For an elaboration of the tasks associated with policy analysis, see White, Irvin L., et al. Work Plan For Completing A Technology Assessment of Western Energy Resource Development. Norman, Okla.: University of Oklahoma, Science and Public Policy Program, 1977.

4.2 WATER

4.2.1 Water Shortages

The results of our impact analyses suggests that western energy development can potentially create water shortages in some western states and give rise to water rights conflicts among potential users by the year 2000.[1] Depending on assumptions made about energy demand and levels of development, our results suggest that by the year 2000 energy development facilities will require 30 to 67 percent of the surface water available in the Upper Colorado River Basin.

Since most western states are already water poor, the water requirements of energy development may substantially influence developmental decisions. For example, as indicated in Chapter 3, conversion technologies can vary significantly in their water requirements: electric power generation requires more water than any synthetic fuel technology; and among synthetic fuel technologies, Synthane may demand 2.6 times more water than Lurgi. Imposing requirements to minimize water consumption could significantly lessen water requirements but could increase economic costs; for example, the use of wet/dry rather than wet cooling can reduce water requirements by as much as 72 percent. Similarly, more labor intensive technologies such as synthetic fuels will create substantially larger population-related water requirements than other technologies, even though such requirements are much smaller than those required by the facilities themselves. Finally, siting alternatives can affect water consumption in terms of the moisture content of coal. For example, siting the same coal conversion technologies in the arid southwest results in the consumption of more water than would be consumed in the Northern Great Plains.

Although the effects of differences in technologies and site conditions will be important to water supplies, western energy development raises the more fundamental question of how competing uses and conflicts will be resolved. The current "system" for resolving potential water availability problems and issues is actually a complex series of interstate compacts, court cases, and doctrines which attempt to establish the rights of individuals, local governments, states, Indian tribes, and the federal government. However, this piecemeal approach to dealing with water problems has produced considerable ambiguity. For example, federal and Indian water rights remain unquantified and, because these rights are potentially quite large, their quantification could seriously affect states and present users. Existing uncertainties and the conflicts that may be created among industrial, agricultural, municipal, and other users by energy development will probably necessitate establishing new mechanisms for resolving disputes. The primary mechanism at the present time is the courts and they are probably inadequate, in part because resolving these complex problems in the court is too time consuming. More fundamentally, the availability of water for energy development is really a political problem and what is needed by way of solution is an acceptable accommodation, not a winner and a loser.

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[1] Reaction to the current drought suggests that water rights conflicts might well arise before 2000.

4.2.2 Water Quality

A. Effluents From Energy Facilities

The goals of the Federal Water Pollution Control Act Amendments of 1972 (FWPCA) are to have water clean enough for boating and fishing by 1977, for swimming by 1983, and to achieve zero discharge of pollutants into navigable waters by 1985.[1] The FWPCA authorizes the regulation of both point sources, such as energy facilities, and nonpoint sources, such as those resulting from runoff and seepage. Individual point sources are regulated by EPA-approved state permitting systems. These permitting systems set effluent standards for toxic and non-toxic pollutants and thermal discharges, both of which have the effect of requiring discharges from energy resource facilities to be treated or cooled. This includes, for example, water used for processing and flue gas desulfurization. It should be noted that the costs of supplying water may make it more economical for the developer to continue to treat and recycle the water as long as possible. Whether because of economic costs or FWPCA requirements, the decision to treat and recycle is often coupled with the decision to treat and reuse water and discharge effluents into on-site evaporative holding ponds rather than to discharge treated effluents into navigable waters. Moreover, because holding ponds are not currently considered potential point sources, facilities which use ponds instead of discharging treated effluents are not required to obtain a permit for the use of ponds. Hence, if this procedure is followed, the Environmental Impact Statement process can be avoided.

Our impact analysis results suggest that the accumulation of toxic pollutants in these ponds can create potentially significant surface and groundwater problems. Quantities of pollutants could be large--ranging from about 11 million to 100 million tons of solids accumulated over 25 years depending upon the type of facility. If accumulation of wet/solids containing heavy metals and/or trace elements are released as a consequence of berm failure, they could produce acute effects in local surface waters. In addition to berm failures, seepage from holding ponds can contaminate groundwater aquifers, which may in turn introduce pollutants into local streams.

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[1] U.S., Environmental Protection Agency. _Clean Water. Report to Congress--1974._ Washington, D.C.: Environmental Protection Agency, 1974.

The significance of these findings is that the FWPCA requirements aimed at promoting water quality may contribute to the use of a technique that can lead to other potentially serious water quality problems. In effect, holding ponds are a potential nonpoint source of pollutants which may increase the problems faced by state and local governments in controlling surface and groundwater pollution.

B. Salinity

Salinity is already a problem in many western surface waters, especially waters of the Colorado River Basin. Salinity is increased by both salt loading (adding salts to the rivers) and salt concentrating (consuming water from the river). Nearly all salt loading can be attributed to nonpoint sources.[1]

Future development in the western states will necessitate attention to several mechanisms for controlling salinity. EPA, under the authority of the FWPCA, has required the 7 states in the Colorado River Basin to establish salinity standards. These states have agreed to maintain the average salinity in the Lower Colorado River Basin at or below 1972 levels. In 1973, the United States and Mexico agreed to limit the salinity of the Colorado flowing into Mexico. To deal with the salinity problems, the Colorado River Salinity Control Act of 1974 provides funding for construction of several desalting and control projects, limits effluents from industrial discharges, and authorizes research projects on future salinity problems and programs. Some problems have already emerged regarding these mechanisms for salinity control. For example, although the 7 states of the Colorado River have set salinity standards in response to EPA requirements, these standards are not currently being implemented under the states' permitting systems. The states of the basin appear to favor a flexible control system in which permits would be approved or disapproved on a case-by-case determination. EPA appears to favor uniform standards which would facilitate enforcement.

Apparently, energy resource development will not pose as much of a salt loading problem as would other uses, particularly irrigated farming.[2] Nor do requirements for consumptive water use for energy resources or related development appear to pose a significant salt concentrating problem. This comparative advantage may be an important political consideration; for example, it would seem to be in California's and Arizona's interest to have any increase in water consumption in the Upper Colorado River Basin be for energy or other nonagricultural uses since less of a salinity problem would be created.

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[1] Refer to Chapter 14.2 for an elaboration of these findings.

[2] See, for example, Holburt, M.B., and V.E. Valentine. "Present and Future Salinity of the Colorado River." *Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers*, Vol. 98 (March 1972, pp. 503-20.

C. Effluents From Populations

The FWPCA also requires existing community public treatment works to install secondary waste treatment by 1977 and "best practicable" waste treatment technologies by 1983. New public treatment works are similarly required to install best practicable techniques by 1983. The impact analyses summarized in Chapter 3 suggest that sewage treatment plants are likely to be quickly overloaded by population increases associated with energy development. Although the quantities of effluents are much less than those associated with energy facilities, several policy problems and issues are likely to arise as a result of large population increases in small western towns. First, poorly treated effluents become, in effect, a point source pollutant which can cause degradation of surface waters. Second, many communities will be unable to afford the costs of either upgrading capacities to meet new demands or of installing secondary treatment required by the FWPCA by 1977, a situation exacerbated by energy development. In cases in which the need for sewage treatment is higher during the construction phase of a facility than during its operation, as it is for gasification and power plant facilities, it may be impracticable to build sewage treatment plants to serve short-term peak demands only to have them underutilized later. Third, insufficient sewer systems may affect other local problems and issues; for example, new housing may be delayed and community health standards may be violated.

4.3 AIR

4.3.1 Emission Control Technologies

Development of western energy resources must be accomplished within the requirements of several categories of air quality regulations: (1) Ambient Air Quality Standards (that limit the atmospheric concentrations of six "criteria" pollutants regardless of their source);[1] (2) New Source Performance Standards (that limit the amount of a given pollutant a stationary source may emit over a given time); (3) Non-Significant Deterioration requirements (that limit the concentrations of pollutants that can be added to areas of relatively clean air); (4) Hazardous

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[1] The six are: carbon monoxide, sulfur dioxide, nitrogen dioxide, hydrocarbons, particulates, and oxidants.

Air Pollutant Standards (that set strict limits on the most dangerous pollutants); and, (5) Mobile Source Standards (that limit emissions of hydrocarbons and carbon monoxide primarily from automobiles).

A recurring question about domestic energy resource production has been how much and what kinds of emission control will be required to meet air quality regulations. This question has become increasingly important in part because of the high costs associated with some control technologies, such as flue gas desulfurization equipment (scrubbers) as compared to alternatives such as using tall stacks that disperse pollutants over wide areas and thereby reduce pollutant concentrations.[1] Questions of control technologies have become especially critical to western energy resource development because western coal is usually considered to be clean enough not to require scrubbers.[2] Our impact analysis results indicate that this often will not be the case.[3]

The impact analysis results reported in Chapters 6-11 indicate that power plants located at most western sites will require scrubbers in order to meet all applicable federal and state air quality standards. Although power plants at some sites can meet New Source Performance Standards without scrubbers, they can be expected to violate Ambient Air Standards and Non-Significant Deterioration (NSD) Standards without them. Because of Class II NSD requirements and strict state standards in Colorado and North Dakota, scrubbers at some sites will have to remove as much as 93 percent of the sulfur dioxide. Moreover, the probability that western coal-fired power plants will require scrubbers has been increased by recent EPA guidelines which do not allow tall stacks to be used in place of scrubbers.[4]

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[1] Over a 15 year operation period, scrubbers are orders of magnitude more expensive than tall stacks. (Refer to Chapter 14.4). Tall stacks are usually used in combination with "intermittent techniques" which utilize favorable meteorological conditions.

[2] This low sulfur content sometimes turns out to be less of a benefit than commonly assumed because many western coals with low sulfur values also have low heating values. Hence, sulfur emissions on a per million British thermal units' basis are not necessarily low.

[3] We used coals with "typical" characteristics for each scenario area in our analyses. While there are coals at each site with a lower sulfur content, it seems more likely that coals with a range of sulfur contents will be blended, particularly over the lifetime of any development.

[4] 41 Fed. Reg. 7450-52 (February 18, 1976). This is because tall stacks reduce concentrations but do not deal with the formation of sulfates in the plume (Chapter 3.3).

4.3.2 Non-Significant Deterioration

In many respects Non-Significant Deterioration (NSD) requirements are an unsettled issue. That is, the costs and benefits of protecting the nation's clean air appear to raise critical questions about balancing energy development and environmental protection. These questions and conflicts between environmentalists and energy developers have contributed to the probability of Congressional intervention. In 1976, both houses of Congress considered bills and amendments that ranged from making existing requirements more strict to declaring a moratorium on protecting clean air areas.

As discussed above, current NSD requirements are likely to substantially influence the use and level of efficiency of scrubbers for coal-fired power plants at many western sites. Our impact analyses also suggest that NSD could influence siting considerations for many technologies because the requirements could effectively establish buffer zones around clean air areas such as national forests and parks within which new facilities could be sited.[1] By far, the largest buffer zones, ranging from 14 to 75 miles, would be required for power plants. Much smaller zones, ranging from 5 to 19 miles, would be required for Lurgi, Synthane, and Synthoil conversion processes. This finding suggests that buffer zones could effectively prohibit the siting of power plants in many parts of the West unless very efficient emission control technologies are used. Hence, buffer zones may be an important consideration in the calculation of trade-offs between onsite power generation and alternatives such as using other conversion technologies or exporting coal to other parts of the country.

4.3.3 Enforcement

The Clean Air Act of 1970 (CAA) creates a dual system of authority and responsibility for regulating air quality. States have substantial control and discretion in setting standards, developing plans for regulating standards, and enforcement. State control is most extensive with respect to ambient air quality and NSD and least extensive for new source, hazardous pollutants, and mobile source regulation. The latter are essentially left to direct EPA control. However, EPA retains ultimate authority to approve or disapprove state air quality plans, to take over state plans if necessary, and to allocate federal funds based on these plans.

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[1] These buffer zones allow pollutants ample distance to dilute by atmospheric mixing to the increments allowed. See Chapter 14.4 for an elaboration of this requirement.

The results of our impact analyses suggest at least one area in which this dual system of control can create problems. We found that the ambient concentrations of hydrocarbons, sulfur dioxide, nitrogen oxides, and particulates produced by energy-related urban development can be as high or higher than those produced by the energy facility itself. This finding was especially critical for hydrocarbons; urban concentrations violated the 3-hour federal standard in all six site-specific scenarios (see Chapter 3). These findings highlight a weakness in the current system of pollution control in that state and local governments have virtually no control over mobile sources, yet they are responsible for meeting ambient air standards that can be violated largely because of the effects of automobile pollution. This finding also suggests that New Source Performance Standards are likely to prohibit new facilities in some urban areas because of existing hydrocarbons levels or because concentrations of other criteria pollutants are approaching the standards.

4.4 PLANNING AND GROWTH MANAGEMENT

4.4.1 Services and Facilities

Most communities impacted by western energy development will face planning and growth management problems that are directly related to large and rapid population increases. Although most areas can expect to experience long-term economic benefits from energy development, several factors will contribute to serious shortages of public and private services in communities during the first several years of development. Our impact analysis results suggest that the most seriously affected communities will probably be those that are small (under 5,000 population), have few planning or institutional capabilities for managing growth and are close to: (1) high labor-intensive technologies such as coal gasification, electric power generation, and oil shale retorting which require large labor forces during construction; and (2) developments which schedule multiple labor-intensive facilities simultaneously. The problems of these communities will be increased by inherent uncertainties in the development process. Uncertainties include inadequate information about the level of development and the plans of energy industries, surrounding towns and states, and the federal government.[1]

Of the public and private facilities and services for which demands will increase, housing and water and sewer systems may be the most basic. Mobile homes are a logical and often typical response to housing needs, although they have the disadvantages of contributing very little to local tax bases and often add to difficulties of providing other services such as law enforcement and fire protection. Permanent housing options suffer primarily from financial constraints, although state and federal housing programs can enhance their feasibility. As discussed in Section 4.2.1, many communities will be unable to provide adequate sewer systems during the short term, resulting in probable violations of the FWPCA and health standards as well as surface water pollution.

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[1] See Chapter 14.5 for an elaboration of these problems.

The demands for health, street maintenance, public safety, and recreational services are also likely to exceed communities' response capabilities. The one exception to this trend is probably school facilities, which usually will not need to expand as much during construction as during operation. Moreover, school systems often have more favorable revenue prospects than do other local government units and in some cases can expect to enjoy substantial revenue surpluses almost immediately after construction begins.[1]

4.4.2 Intergovernmental Relations

Increased strain in intergovernmental relations is another impact of rapid population growth. As noted in Chapter 3, one of the major sources of strain is that the benefits of public revenue increases often accrue to counties or school districts while cities are faced with expanded demands for services. Many problems also arise between state and local units of government, such as state limits on taxation rates and debts ceilings (as is the case in North Dakota), prohibitions on the transfer of state revenues to cities or counties (as is the case in Utah), and fragmentation of authority and responsibility among cities, counties, councils of governments, special districts, and state agencies. Many western states have responded to some of these problems through mechanisms such as community development agencies, training programs, and earmarking tax funds for impacted communities.

Federal assistance is also available to communities for most service areas through general revenue sharing and grants-in-aid. However, few federal grant or loan programs are explicitly directed towards the small, predominantly rural towns typically hardest hit by energy development. Because competition is keen for federal dollars and most small communities lack experience in applying for assistance, little if any of these traditional sources of revenue are likely to reach communities impacted by western energy development. Two recent federal programs, the In Lieu of Tax Payment Act of 1976 and the Federal Coal Leasing Act of 1975, appear better suited to these communities. These acts increase state and local revenues and establish priorities for applying these funds to areas impacted by resource development.

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[1] This can largely be attributed to the fact that school districts often are large geographical areas which incorporate the energy facilities.

4.5 RECLAMATION

Several aspects of the natural environment may become important policy issues as a result of western energy development, including air and water quality (as discussed above), disturbance of ecosystems, and aesthetic values of the land. One of the more problematic of these issues is likely to be reclamation, in part because of the large amounts of land that will be disturbed by increased coal production. The impact analysis shows that existing conditions in many parts of the West will make successful revegetation difficult. For example, reclamation will be most difficult in the arid Southwest because of low and erratic average rainfall and poor soil quality.

Because of the constraints posed by western ecosystems, water requirements and water management become a critical policy component in the reclamation process. Especially in the Southwest, successful reclamation may be impossible without large-scale commitments to irrigation. The basic issue therefore, concerns the trade-offs between using the water for irrigation and for other areawide uses such as agriculture. Furthermore, using water for reclamation may be an important factor in decisions about developing on-site coal conversion technologies (these require more water in the Southwest than they would in other parts of the eight state study area) or exporting the coal. Alternatively, water problems may lead to questions about requirements for mined land to be returned to its original contour. For example, existing regulations in some states prohibit the reclamation process from shifting the layers of overburden to allow more fertile soils to be placed on top. In some parts of the West, this means that land will be returned to an essentially non-productive state and prevent alternatives such as using the land for residential developments or community facilities (in cases where mines are not in isolated locations) from being considered.[1]

Reclamation also raises intergovernmental problems because it will take place in a legal, regulatory, and enforcement network defined primarily by the states, but including federal and local input. One problem that has surfaced in this respect is that many western states have piecemeal approaches to formulating, coordinating, and enforcing reclamation laws, largely because reclamation laws are a relatively recent phenomenon in the West.

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[1] For a discussion of potential recreational or residential uses for surface mined land, see Carter, Ralph P., et al. *Surface Mined Land in the Midwest: A Regional Perspective for Reclamation Planning*, for the U.S. Department of the Interior. Argonne, Ill.: Argonne National Laboratory, 1974, pp. I-60-I-63.

A more significant problem may be the conflict that has already arisen regarding state control over reclamation on federal lands. Since substantial quantities of coal underlie federal lands and no federal reclamation legislation has been adopted, the extent of states' rights and authority over these lands has become an important jurisdictional issue. Although recent regulations issued by the Department of Interior establish federal pre-emptive control over state reclamation standards, state laws generally apply to all mining activities within their boundaries regardless of ownership, many states continue to enforce their laws on federal lands, and specific disputes have been introduced into the courts during the past year.[1]

4.6 CONCLUSION

The significance of each of the problems and issues discussed above will depend on factors such as national energy demands, levels and rate of development of western energy resources, and resolution of ambiguities in current regulation systems. The results of the impact analyses also show that the interaction of different technologies with various existing conditions (such as community size, coal characteristics, and rainfall) will be critical to the kind and severity of problems and issues which emerge. This finding is important because it suggests that careful consideration of siting alternatives will be one method for preventing or lessening the severity of many impacts. However, our preliminary policy analysis suggests that few if any decision-making mechanisms exist for bringing together parties-at-interest from both the private and public sectors which would allow for the consideration of siting alternatives. Hence, nearly every category of problems and issues is likely to be affected by this current inadequacy of the policymaking system.

We have identified and discussed selected problems and issues in this chapter; policy analysis during the remainder of the project will take a more comprehensive look at problems and issues likely to arise as consequence of western energy development. Policy analysis in the future will also include several steps designed to inform policymakers by: (1) relating problems and issues to EPA's environmental control programs; (2) identifying and describing relevant policy systems, including governmental and nongovernmental participants, institutional arrangements, and existing laws and regulations; (3) determining the significance of each problem, and (4) identifying, evaluating, and comparing policy alternatives and implementation strategies for dealing with the most significant problems and issues.[1]

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[1] While there is still considerable ambiguity concerning this jurisdictional conflict, many western states feel strongly that they have control over reclamation within their borders. Wyoming's recent lawsuit against Interior suggests that states are being allowed substantial control. This issue is discussed in more detail in Chapter 14.

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[1] For an elaboration of future policy analysis see: White, Irvin L., et al. *Work Plan for Completing a Technology Assessment of Western Energy Resource Development*. Norman, Okla.: University of Oklahoma, Science and Public Policy Program, 1977.

CHAPTER 5

PLANS FOR COMPLETING THE PROJECT

5.1 INTRODUCTION

Although a separate, detailed work plan has been prepared and distributed, a brief, general description of plans for completing the technology assessment is presented below.

5.2 BACKGROUND AND SUPPORTING MATERIALS

A number of background and supporting materials either have been or are being prepared that are not being circulated with this progress report. Among these are six energy resource development systems (ERDS) that are described in the *First Year Work Plan*.[1] The primary purpose of the ERDS is to provide a description of the technologies and the rules and regulations that control their deployment and operation. These are baseline data that were required before impact analysis could be undertaken. Technologies descriptions for all six resources have been completed, reviewed externally, and are now being revised. The required data on federal and state rules and regulations have been collected and are to be sent out for review within the next few months. A final ERDS report integrating descriptions of the technologies and the laws and regulations will be distributed in the fall of 1977.

Other background and supporting materials that will be made available are subcontractor reports, a series of background policy analysis papers, and a final impact analysis report. Two subcontractor reports have been completed: Michael Rieber and Shao Lee Soo, "Route Specific Cost Comparisons: Unit Trains, Coal Slurry Pipelines and Extra High Voltage Transmission"; and Water Purification Associates, *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the*

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[1] White, Irvin L., et al. *First Year Work Plan for a Technology Assessment of Western Energy Resource Development*. Washington, D.C.: U.S., Environmental Protection Agency, 1976.

Western United States.[1] The Rieber and Soo report is included as Appendix B to this report; the WPA report is being published as a separate EPA publication.

Under a subcontract with the University of Oklahoma, the Federation of Rocky Mountain States is conducting a planning study that emphasizes differences in planning for permanent and temporary growth. The Federation's final report will either be issued as a separate report or appended to one of the other reports described in this section.

Each of the background policy analysis papers will focus on a category of substantive problems and issues. These papers will: (1) identify and define problems and issues within the category; (2) relate these problems and issues to EPA's environmental control programs; (3) identify and describe relevant policy systems in terms of governmental and nongovernmental participants, existing institutional arrangements, laws, regulations, policies and programs, established goals and objectives, and existing and potential conflicts; (4) determine the significance of these problems, issues, and policy systems to the future of western energy resource development; (5) identify those problems and issues that warrant an in-depth analysis of alternative policies and implementation strategies; and (6) identify, evaluate, and compare policy alternatives and implementation strategies for dealing with these problems and issues. Each of these papers will also consider inter- and intra-governmental problems and issues and special concerns that arise because of Indian and federal ownership.

The final impact analysis report will be a revised version of Chapters 3 and 6-12 of this report. Although considerable progress has been made in achieving our analytical objectives, the impact analyses conducted to date must be extended and refined. The changes to be incorporated are: lower levels of development; the addition of four technological alternatives (enhanced oil recovery, *in situ* oil shale, geothermal, and an additional uranium mine and mill); sensitivity or parametric analyses of critical factors; and a revision of the format for reporting results to emphasize building blocks which relate residuals and impacts to separate technological and locational alternatives.

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[1] Water Purification Associates. *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*, Final Report, for University of Oklahoma, Science and Public Policy Program. Washington, D.C.: U.S., Environmental Protection Agency, forthcoming.

5.3 THE FINAL TECHNOLOGY ASSESSMENT REPORT

In addition to the final technology assessment report addressed to EPA, several summary reports designed to communicate to specific audiences will be prepared, including reports for local and state officials and agencies, federal agencies and the Congress, the energy industry, and other private parties-at-interest. The basic report will synthesize the detailed results reported in the background and supporting materials described above, summarizing: impacts; costs, risks, and benefits; substantive policy problems and issues; and policy alternatives and implementation strategies.